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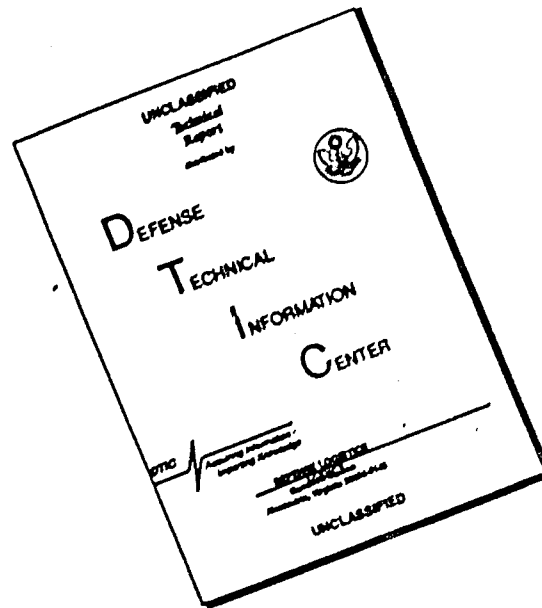
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STORABLE PROPELLANT DATA
FOR THE TITAN II PROGRAM

Prepared by
BELL AEROSYSTEMS COMPANY
Division of Bell Aerospace Corporation
Buffalo 5, New York

Ralph R. Liberto
Project Engineer

Second Progress Report
Contract Number AF04(694)-72
1 September through 31 December 1961

Bell Report No. 8182-933003
March 1962

Prepared for
AIR FORCE BALLISTIC SYSTEMS DIVISION
Air Force Systems Command
Los Angeles 45, California

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FOREWORD

This progress report was prepared by the Bell Aerosystems Company, Division of Bell Aerospace Corporation, for the Air Force Ballistic Systems Division, Air Force Systems Command. The report covers the results of experimentation conducted under Contract AF04(694)-72 during the period 1 September through 31 December 1961.

Captain C. D. James of AFBSD is the Project Officer and Mr. Glen W. Howell of the Space Technology Laboratories, Inc., Los Angeles, California, is the Technical Director. Mr. Ralph R. Liberto, Project Engineer, is directing the study effort at the Bell Aerosystems Company.

Harold W. Stafford
Technical Editor

ABSTRACT

Tests were conducted to determine the effects of the Titan II propellants on metals and non-metals and the effects of metals on fuel decomposition. The Titan II propellants are N_2O_4 as the oxidizer and a 50/50 blend of UDMH and N_2H_4 as the fuel.

The fire hazards of various materials were determined during drip tests with N_2O_4 and 50/50 fuel blend separately.

Storability data is presented for the fuel blend at $60^\circ \pm 5^\circ\text{F}$. Also, fuel blend separation data was determined after storage at $60^\circ \pm 5^\circ\text{F}$.

Presented is the data from the U.S. Bureau of Mines regarding flammability characteristics of 50/50 fuel blend - N_2O_4 - air - water mixtures.

SUMMARY

The vapor pressure of the 50/50 fuel blend was measured at 80°F at both 25% and 75% ullage volume. This was a repeat test, again demonstrating the slight change of vapor pressure with a change in ullage.

Additional flash and fire points of 50/50 fuel blend dilutions with various amounts of water were measured.

The 50/50 fuel blend was stored for 15 months at 60° ± 5°F with no significant change in composition or pressure. The fuel was insensitive to shock after this storage period. Also, a 12-month storage test was conducted to determine if the fuel blend separated. The results showed that no separation occurred.

Compatibility tests with stainless steels and 50/50 fuel blend indicated no significant difference in corrosion rates when the stainless steels were acid-pickled or merely degreased.

Cobalt alloys showed good resistance to the 50/50 fuel blend at 160°F and to N₂O₄ at 65°F.

Electroless nickel plating on 1018 steel and on 2014 aluminum alloy was resistant to the 50/50 fuel blend at 160°F for 46 days and to the N₂O₄ at 65°F for 30 days; however, the plating is susceptible to attack by dilute nitric acid.

A cis-4-polybutadiene rubber showed good resistance to the 50/50 fuel blend at 160°F for 30 days.

Of the five coatings tested, only Proseal 333, a butyl rubber coating, was resistant to the 50/50 fuel blend and N₂O₄ during splash and drip tests.

Graphite materials (CCP-72, Graphitar 39, and Graphitar 86) were compatible with the 50/50 fuel blend at 160°F for 30 days and with N₂O₄ at 65°F for 30 days. Graphitar 14 showed poor resistance to the fuel blend.

Sixteen metals were exposed to the fuel blend sealed in glass ampules and stored in a bath at 160°F for 14 days. Fuel blend decomposition was determined by a weight loss technique. The results indicated that gold plating and magnesium alloy AZ 31BO caused the highest fuel blend decomposition (1.9% and 1.26%, respectively); this was 30 and 25 times greater than the fuel blend decomposition caused by 304L stainless steel.

Twenty-seven materials were exposed to a 50/50 fuel blend drip test at room temperature to determine if a fire hazard exists. Only cobalt oxide ignited. Iron oxide exhibited sparks and glowing, but no ignition. Additional tests revealed that the iron oxide must be heated to 115°F before ignition occurs from fuel blend drippings. Similar tests showed that a rusted steel band must be heated to 180°F before ignition occurs from fuel blend drippings.

Forty-six materials were exposed to an N₂O₄ drip test at room temperature to determine if a fire hazard exists; some solids were also soaked in N₂O₄ for a short time. Aniline and the 50/50 fuel blend were the only liquids to ignite. Of the solids tested, only masking tape and two rubber gloves ignited.

Dilute nitric acid (70%) causes corrosion of 2014 aluminum alloy. Consequently, an aluminum tank containing residual N₂O₄ should be purged dry to preclude nitric acid formation.

Mechanical and physical property measurements of various samples of Teflons TFE 6 and TFE 7 were made after exposure to N₂O₄ at 65°F for various time intervals. All tests indicated only slight changes in properties after N₂O₄ exposure.

Based upon visual examination, Aclar (a fluorohalocarbon) and Amerplate (a polyvinyl chloride) showed good resistance to N₂O₄ at 65°F for 30 and 22 days, respectively. Except for a significant reduction in elongation, a cross-linked polyethylene showed good resistance to N₂O₄ at 65°F for 30 days.

Several ethylene-propylene rubbers showed poor resistance to N₂O₄ at 65°F for 30 days.

Permeability tests with Teflon TFE 7 and Teflon FEP showed that the latter is three times less permeable to N₂O₄ under identical conditions.

Omniseals (Teflon-covered, stainless steel O-rings) showed good dynamic sealing qualities in N₂O₄ under 100 psig pressure. Identical dynamic seal tests failed with Bal Seals (Teflon-covered stainless steel) and resin-cured butyl rubber O-rings.

The addition of water to the 50/50 fuel blend resulted in a mixture which required higher temperatures for spontaneous ignition in N₂O₄ - air mixture than was required for ignition of undiluted fuel blend.

The lower limit of flammability of fuel blend vapor in air was apparently unaffected for water vapor concentrations to 21.4 volume percent.

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SYMBOLS/ABBREVIATIONS USED IN THE TEXT

AFBMD	Air Force Ballistic Missile Division
AFBSD	Air Force Ballistic Systems Division
AFFTC	Air Force Flight Test Center
ASD	Aeronautical Systems Division
ASTM	American Society for Testing Materials
JANAF	Joint Army -- Navy -- Air Force
FUEL BLEND	Nominal 50/50 blend by weight of UDMH and N_2H_4 MIL-P-27402 (USAF)
50/50 FUEL BLEND	Nominal 50/50 blend by weight of UDMH and N_2H_4 MIL-P-27402 (USAF)
HNO_3	Nitric Acid
NO_2	Nitrogen Dioxide
N_2H_4	Hydrazine, Specification Grade MIL-P-26536A (USAF)
N_2O_4	Nitrogen Tetroxide, Specification Grade MIL-P-26539
UDMH	Unsymmetrical Dimethylhydrazine, Specification Grade MIL-D-25604B (ASG)
cc	Cubic Centimeter(s)
MPY	Mils per Year
RMS	Root Mean Square
SIT	Spontaneous Ignition Temperature(s)

SECTION I

INTRODUCTION

Work on this Air Force program principally concerns the compilation of propellant data in support of the Titan II ballistic missile system. The propellants being studied are nitrogen tetroxide (N_2O_4) as the oxidizer, and a nominal 50/50 blend of unsymmetrical dimethylhydrazine (UDMH) and hydrazine (N_2H_4) as the fuel.

The specific objective of this phase of the study is to up-date the Titan II propellant data which appears in a handbook published in June 1961 by the Bell Aerosystems Company for the Air Force Flight Test Center (Report AFFTC TR-61-32). The ultimate objective is to issue a revised, loose-leaf handbook so that subsequent additions or changes can easily be made.

This report contains information generated by laboratory tests conducted during the period 1 September through 31 December 1961.

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SECTION II

PHYSICAL PROPERTIES

A. VAPOR PRESSURE OF 50/50 FUEL BLEND

Repeat tests were conducted at 80°F using specification-grade 50/50 fuel blend to determine the effect of varying the ullage from 25% to 75% on its vapor pressure. An all-glass evacuated system and an isoteniscope described in Reference 1 were used. Modification of the procedure was made to incorporate use of a glass-coated magnetic stirring bar in the isoteniscope. This was done to ensure a homogeneous mixture of the fuel blend when thawing was complete. (The fuel blend was frozen prior to evacuating the system).

At 80°F, the vapor pressure at 25% ullage was 3.96 psia and at 75% ullage it was 3.06. Slight differences between the results of this data and that reported in References 2 and 3 are attributed to stirring.

B. FLASH AND FIRE POINTS OF 50/50 FUEL BLEND WITH VARIOUS WATER DILUTIONS

The flash and fire point measurements were repeated for the fuel blend as a function of water dilution by volume reported in Reference 1. An ASTM procedure given in Reference 4, was followed. The only modification was in the material of construction of the cup. Instead of brass, 304 stainless steel was used. The data obtained is presented in Table 1 and plotted in Figure 1. These tests indicate that the fuel blend must be diluted with approximately an equal volume of water before the fire hazard is reduced appreciable. A dilution of three volumes of water to two volumes of fuel blend is required to increase the flash and fire point temperature to 180°F.

C. SHOCK SENSITIVITY

Tests were conducted to determine the shock sensitivity of the fuel blend stored at 60° ± 5°F for 15 months in an 1100 aluminum alloy tank and glass bottle. Determinations were made with a drop-weight tester developed by Olin Mathieson Chemical Corporation and recommended by the JANAF Group on Liquid Propellant Test Methods. The fuel was found to be insensitive to impact.

TABLE 1
FLASH AND FIRE POINTS OF THE 50/50 FUEL BLEND WITH VARIOUS WATER DILUTIONS

Volume Percent Water in Fuel Blend	Flash Point (°F)			Fire Point (°F)		
	Sample 1	Sample 2	Average	Sample 1	Sample 2	Average
Undiluted	32.0	37.4	34.7	32.0	37.4	34.7
10	39.2	44.6	41.9	39.2	44.6	41.9
20	53.6	57.2	55.4	53.6	57.2	55.4
30	82.4	82.4	82.4	82.4	82.4	82.4
40	111.2	116.6	113.9	118.4	116.6	113.9
50	147.2	143.6	145.4	158.0	149.0	153.5
60	179.6	177.8	178.7	221.0	215.6	218.3

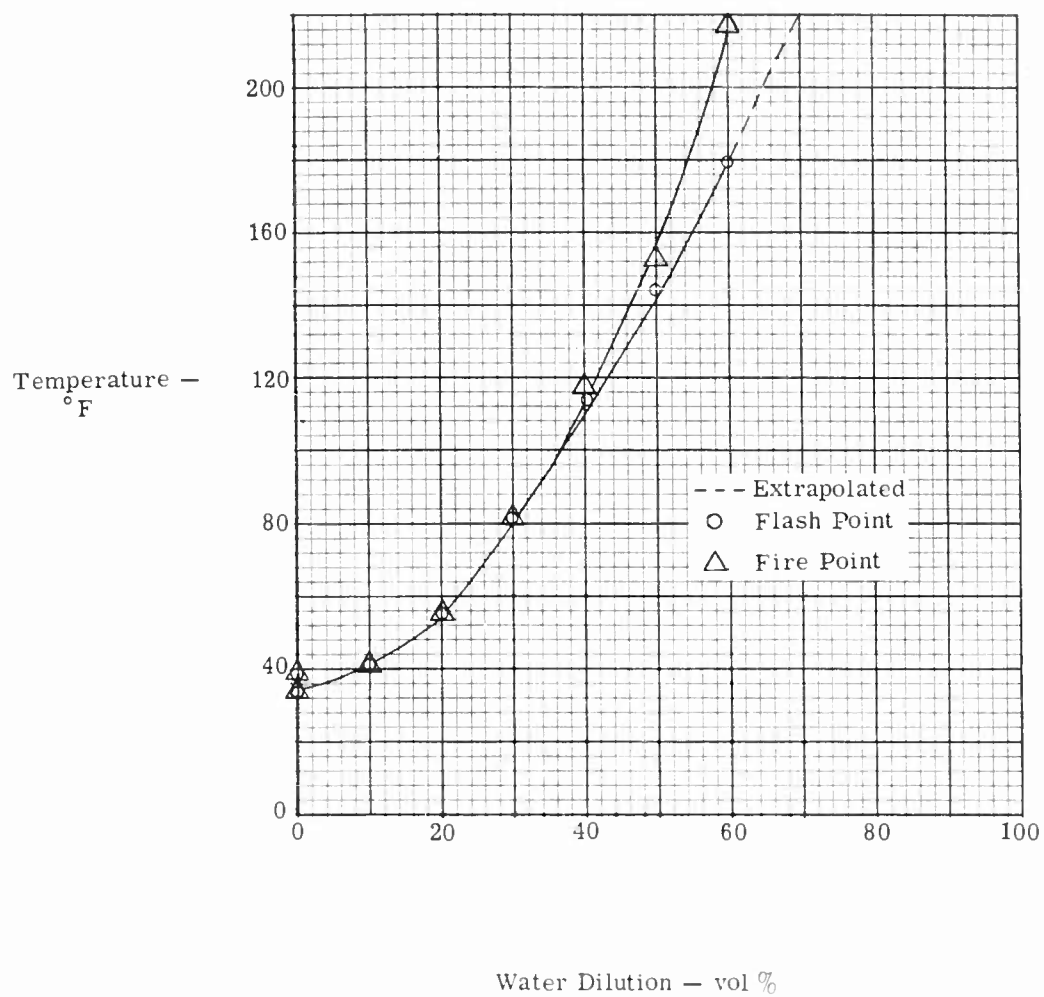


Figure 1. Flash and Fire Points of 50/50 Fuel Blend with Various Water Dilutions

SECTION III

MATERIALS COMPATIBILITY

Results of material compatibility tests of various metals and nonmetals with the Titan II propellants are presented in this section. The tests were conducted in a similar manner to those performed in an earlier program at Bell Aerosystems Company (Reference 3). Information from these tests has resulted in rating the materials as to their compatibility with the Titan II propellants. An explanation of these ratings is presented in Appendix A of this report.

A. EFFECTS OF 50/50 FUEL BLEND ON METALS

1. Stainless Steels

As stated in Reference 3, staining and minor deposits were found on vapor-degreased samples of 304L, 321, 347, 410, and 17-7 PH stainless steel coupons in the vapor phase after exposure to fuel blend at 160°F for 90 days. Under similar conditions, deposits were not found on PH 15-7 Mo, 316, AM355, and 17-4 PH molybdenum-bearing stainless steels. Types 304L, 321, 347, and 410 stainless steels, which were acid-pickled, did not exhibit deposits in the vapor phase after 14 days exposure at 160°F.

To determine the relative effects of exposure time, acid-pickling, and molybdenum content, six specimens each of 304L, 316, 347, 17-7 PH, and AM350 stainless steels were prepared for further tests. Three specimens of each type of stainless steel were acid-pickled and three were merely degreased prior to exposure to the fuel blend at 160°F for 90 days.

A light-tan stain existed in the vapor phase of all the specimens and was suspected of originating from the plastic screw-top caps. A qualitative test for the presence of phenolics using a procedure outlined in Reference 5 was performed on the stain. A positive test was obtained. Prior to evaluation, all the specimens were cleaned with a 10% sodium hydroxide solution which readily removed the stain. Except for a slight stain at the interface, all the specimens were unaffected. Microscopic examination and qualitative testing with a potassium ferricyanide solution showed the presence of steel particles imbedded in the surface of the unpickled stainless steel specimens.

All these metals were resistant to the fuel blend and were given an "A" rating. Test results are shown in Table 2. It is recommended that all stainless steels be acid-pickled prior to use to eliminate any imbedded particles resulting from fabrication or cutting techniques.

2. Cobalt Alloys

Haynes Stellite 6K and 21 (cobalt alloys) were tested in the 50/50 fuel blend at 160°F for 90 days. Stellite 6K contains a maximum of 1.5% molybdenum, while Stellite 21 contains 5.0% to 6.0% molybdenum. Both metals were unaffected by the fuel blend and were given an "A" rating. The test results are shown in Table 2.

3. Platings

Specimens of 1018 steel having an RMS finish less than 16, and specimens of 2014 aluminum alloy, both pore-free electroless nickel-plated, were exposed to the fuel blend at 160°F for 133 and 46 days, respectively.

The electroless nickel coating, 2 mils thick, was plated on the 1018 steel by Michigan Chrome and Chemical Company of Detroit, Michigan, using the Vea Chemical Process. The 2-mil-thick nickel coating was plated on the 2014 aluminum alloy by the Keystone Chromium Company of Buffalo, New York, using the Kanigen Process.

The plating, resulting from both these processes, was unaffected. The results are shown in Table 2.

B. EFFECTS OF 50/50 FUEL BLEND ON NONMETALS

1. Plastics

Kynar (vinylidene fluoride) cracked, flaked, and laminated after exposure to the fuel blend at 160°F for 30 days; however, at room temperature (70° to 80°F), the Kynar showed good resistance. Test results are given in Table 3.

2. Elastomers

A cis-4-polybutadiene rubber, designated as formulation 35, was received from the Elastomers Section of ASD, Wright-Patterson AFB. Samples showed good resistance after exposure to the fuel blend at 160°F for 30 days; however, because of a slight sediment found in the fuel, the material was given a "B" rating. Butyl rubbers (940 x 559 and Parker B480-7) and two fluororubbers (18007 and 18057) showed poor resistance to the fuel blend at 160°F. The results are shown in Table 3.

TABLE 2

COMPATIBILITY OF METALS WITH 50/50 FUEL BLEND AT 160°F

Propellant Quantity: One fluid ounce per test tube.
 Specimens: Rectangular coupons approximately 5 square inches in area.
 Number of Specimens: Three per material in individual test tubes.
 Condition: Partial immersion - static.
 Apparatus: Pressure-tight, screw-top, aluminum-foil-gasketed, culture test tubes containing nitrogen gas.
 Data: Average of three specimens.

Material	Time In Days	% Wt Change	Corrosion Rate - MPY	Rating ^a	Remarks
COBALT ALLOYS					
Haynes Stellite 6K	3	-0.0047	0.158	A	Slight stain at interface
Haynes Stellite 6K	90	-0.0073	0.008	A	Slight stain at interface
Haynes Stellite 21	3	None	None	A	
Haynes Stellite 21	90	+ 0.0004	-	A	
STAINLESS STEELS					
304L (Degreased & Pickled)	90	-0.0134	0.018	A	
304L (Degreased only)	90	-0.0320	0.042	A	
316 (Degreased & Pickled)	90	-0.0109	0.014	A	
316 (Degreased only)	90	-0.0519	0.067	A	
347 (Degreased & Pickled)	90	-0.0172	0.023	A	
347 (Degreased only)	90	-0.0211	0.028	A	
AM350 SCT (Degreased & Pickled)	90	-0.0032	0.004	A	
AM350 SCT (Degreased only)	90	-0.0081	0.009	A	
17-7PH (RH950-SCT) (Degreased & Pickled)	90	-0.0040	0.006	A	
17-7PH (RH950-SCT) (Degreased only)	90	-0.0165	0.024	A	
ELECTROLESS NICKEL PLATE					
On 2014 Aluminum Alloy	46	-0.0175	0.022	A	
On 1018 Steel	133	-0.0042	0.005	A	

a - Definitions of ratings are given in Appendix A.

TABLE 3
COMPATIBILITY OF NONMETALS WITH 50:50 FUEL BLEND FOR 30 DAYS

Propellant Quantity: One fluid ounce per test tube.
 Specimens: ASTM D1457-56T die tensile bars or rectangular bars.
 Number of Specimens: Three per material in individual test tubes.
 Condition: Full immersion - static.
 Apparatus: Pressure-tight, screw-top, aluminum-foil-gasketed, culture test tubes containing nitrogen.
 Data: Average of three specimens.

Material	Temp. °F	Shore Hardness Control	Tensile Ksi Control	% Elong. Control	Before			After			Rating ^a	Remarks		
					Outgassing			Outgassing						
					% Wt Change	% Vol Change	Shore Hardness	Tensile Ksi	% Elong.	% Wt Change			% Vol Change	
PLASTICS														
Kynar	70-80	80D	6.69	23.8		+8.95	+19.30	76D	6.01	26.2	+2.68	+6.58	C	Shore D decrease 4 units, sample turned dark brown
ELASTOMERS														
Formulation 35 (Cis-4-Poly-butadiene)	160	75A	1.63	286		+4.91	+ 8.00	80A	1.58	238	+ 1.19	+ 0.31	B	Slight sediment
Butyl 940x559	160	70A	1.22	250		+10.50	+19.50	67A	1.07	300	+5.55	+11.20	D	Sample blistered, 7-day test
Parker B480-7	160	-	-	-	-	-	-	-	-	-	-	-	D	Became tacky and flowed in 7 days
18007 and 18057	160	-	-	-	-	-	-	-	-	-	-	-	D	Dissolved 1 day
GRAPHITES														
Graphitar 14	160	-	-	-	-	+ 1.39	-	-	-	-	+4.96	-	D	Samples crumbled
Graphitar 39	160	-	-	-	-	+ 0.15	0	-	-	-	+0.34	0	A	
Graphitar 86	160	-	-	-	-	+ 1.02	0	-	-	-	+ 1.31	0	A	
National Carbon CCP-72	160	-	-	-	-	+ 0.28	0	-	-	-	+0.50	0	A	
LUBRICANT														
PD788	160	-	-	-	-	-	-	-	-	-	-	-	D	Hardened and dissolved within 24 hours

— Definitions of ratings are given in Appendix A.

a - Definitions of ratings are given in Appendix A.

3. Paints

Several paints were tested for resistance to the 50/50 fuel blend and the results are given in Table 4. Mild steel specimens were coated with the paints following the procedures outlined by each manufacturer. The paints were first exposed to splash tests patterned after a procedure outlined in Reference 6. Briefly, the procedure consists of immersing the coated specimen in the fuel blend at $80^{\circ} \pm 3^{\circ}\text{F}$ for one minute and then allowing the specimen to air dry for 24 hours at $80^{\circ} \pm 3^{\circ}\text{F}$ and a relative humidity no greater than 80%. Only Proseal 333, a butyl rubber coating, was unaffected by splash and drip tests with the fuel blend. The drip test was conducted by dripping fuel blend at an approximate rate of 1 cc per minute on the specimen while partly immersed in water. With the specimen at a 45° angle, the fuel was allowed to drip for 2 hours on the portion of the specimen exposed to the atmosphere. A third test with this coating was conducted by immersing a coated specimen in the fuel blend at room temperature for 2 hours. Only slight blistering occurred during the 2 hours. Of the coatings tested and found in the literature, Proseal 333 is the most resistant to the fuel blend.

4. Lubricants

A fluorocarbon lubricant (PD 788) obtained from Frankford Arsenal was exposed to fuel blend at 160°F for one day. The grease hardened and discolored within this period (see Table 3).

5. Graphites

Four carbon-graphite materials used as bearings and seals were immersed in the fuel blend at 160°F for 30 days. Tests with National Carbon CCP-72 and Graphitars 14, 39, and 86 were completed and the results are shown in Table 3. Only Graphitar 14 was adversely affected.

TABLE 4
SPLASH AND DRIP TESTS WITH 50/50 FUEL BLEND

<u>Material</u>	<u>Splash Test</u>	<u>Drip Test</u>	<u>Rating^a</u>
Proseal 333	Coating unaffected	Coating unaffected (2 hours)	A
Markal DA-8 Aluminum Alloy	Coating washes off	Coating washes off	D
Markal DA-8 Gray	Coating washes off	Coating washes off	D
Markal DA-9 Aluminum Alloy	Coating washes off	Coating washes off	D
Aluminous Paint	Blisters	Blisters	D

a - Definition of ratings are given in Appendix A.

C. EFFECTS OF METALS ON 50/50 FUEL BLEND DECOMPOSITION

Additional tests were conducted to determine the effects of metals on fuel blend decomposition after 14 days exposure at 160°F using the procedure described in Reference 7. As before, all samples were run in triplicate, with 0.01% representing the experimentally determined value for the control. The metal specimens used and the results of the test are listed in Table 5.

TABLE 5
EFFECTS OF METALS ON 50/50 FUEL BLEND DECOMPOSITION
AFTER 14 DAYS EXPOSURE AT 160°F

Material	Decomposition - Wt%			
	Samples			
	1	2	3	Average ^e
<u>ALUMINUM ALLOYS</u>				
2014 Nickel-Plated	0.81	0.31	0.43	0.51
7075	a	0	0.01	0
<u>STAINLESS STEELS</u>				
304L	0	0.10	0.08	0.05
304L Soldered (60% lead + 40% tin)	0.12	0.08	a	0.06
347 Gold-Plated	1.41	2.37	1.93	1.89 ^b
347 Silver-Plated	0.01	0.02	0.02	0.01
410 Rusted ^c	a	0.07	0.19	0.08
316	0.17	0.36	0.12	0.17
PH15-7 Mo	0.10	0.11	0	0.06
AM 355	0.03	0.76 ^d	0.07	0.04
<u>MISCELLANEOUS ALLOYS</u>				
Beryllium Copper	0	0.02	0.03	0.01
Brass (QQB613)	0	0	0.03	0
Bronze (QQB671A)	0.01	0.04	0.01	0.01
Copper	0.04	0	0.05	0.02
K-Monel	0.01	0.01	0.01	0
Magnesium AZ31BO	1.52	1.05	1.23	1.26
Stellite 21	0.02	0.01	0.01	0
<u>CONTROLS</u>	0.01	0.01	0.02	0.01

a - Sample lost or leaked.

b - Test repeated with same samples resulted in average decomposition of 0.14%.

c - Test with N₂H₄ resulted in average decomposition of 0.53% and 0.01% control for N₂H₄.

d - Value not used in average.

e - Control value 0.01% was subtracted.

The presence of corrosion products in the form of a grayish coating on the surface of the magnesium alloy, AZ 31BO, and sediment in the bottom of the ampule gave visual substantiation of a high fuel blend decomposition. This test indicated a 1.26% decomposition or about 25 times the decomposition found with 304L stainless steel which would be considered a safe material on the basis of the test results. Another high fuel blend decomposition value was obtained from gold plating. The decomposition value (1.90%) is about 30 times that of 304L stainless steel; however, a repeat test with the same gold-plated samples yielded a decomposition value of 0.14%. This is probably^o due to passivation of gold plating during the first test.

D. FIRE HAZARDS OF MATERIALS EXPOSED TO 50/50 FUEL BLEND

Tests were conducted at room temperature and at one atmosphere to determine if materials known to be incompatible, or potentially incompatible, would constitute a fire hazard in the event of contact with the fuel blend.

The procedure that was used for testing various materials with the fuel blend is as follows. A 400cc beaker was used to hold the test material and then approximately 2 to 3cc of the fuel blend were dripped on the test sample by means of a syringe. Observations were then made and any significant changes were noted for a minimum period of one hour. No ignition constituted the absence of a fire hazard under the test conditions.

The results of these tests are shown in Table 6. Only the cobalt oxide ignited when fuel blend was dripped on it. Iron oxide exhibited sparks and glowing, but no ignition; copper oxide was reduced to metallic copper, but no ignition. Similar tests are recommended for all materials where information is lacking on the fire hazard potential of the material when used in areas where fuel spills may occur.

Since iron oxide or rust was suspected of being a hazardous material, additional tests were conducted to determine this, both with reagent-grade iron oxide and with rust on a steel band. The apparatus shown in Figure 2 consists of a 4-liter beaker with a aluminum alloy plate covering the bottom. Affixed to this plate is a chrome-alumel thermocouple, the end of which is covered with approximately 1 gram of reagent-grade ferric oxide, spread evenly in a circle with a diameter of about 1.5 inches. The beaker and contents were then set upon a hot plate, heated to the desired temperature, and maintained at that temperature for 15 to 20 minutes. After this stabilization period, about 0.5cc of the fuel blend was dripped onto the ferric oxide and observations were made.

TABLE 6

FIRE HAZARD TESTS OF VARIOUS MATERIALS EXPOSED
TO 50/50 FUEL BLEND AT ROOM TEMPERATURE

Material	Observations
<u>LIQUIDS</u>	
Kel-F Fluorocarbon Oil 3	No ignition
<u>SOLIDS</u>	
Asphalt	No ignition, softened
Asbestos (shredded)	No ignition
Blotter	No ignition
Cardboard	No ignition
Cobalt (filings)	No ignition
Cobalt Oxide (powder)	Glowing, seconds later ignition
Copper (shredded)	No ignition
Copper Oxide (wire)	Fuming occurred, copper oxide reduced to copper, no ignition
Cotton Cloth	No ignition
Dacron Yarn	No ignition
Dust	No ignition
Grass (dry)	No ignition
Iron Oxide (powder)	Glowing and some sparking, no ignition
Iron Rust on Steel	No ignition
Leather	No ignition
Leaves (dry)	No ignition
Molykote G	No ignition
Mylar	No ignition
Orlon Yarn	No ignition
Paper	No ignition

TABLE 6 (CONT)

Material	Observations
<u>SOLIDS (CONT)</u>	
Rags (oily)	No ignition
Rubber (natural)	No ignition
Sawdust	No ignition
Styrene (styrofoam)	No ignition
Tobacco	No ignition
Vermiculite	No ignition

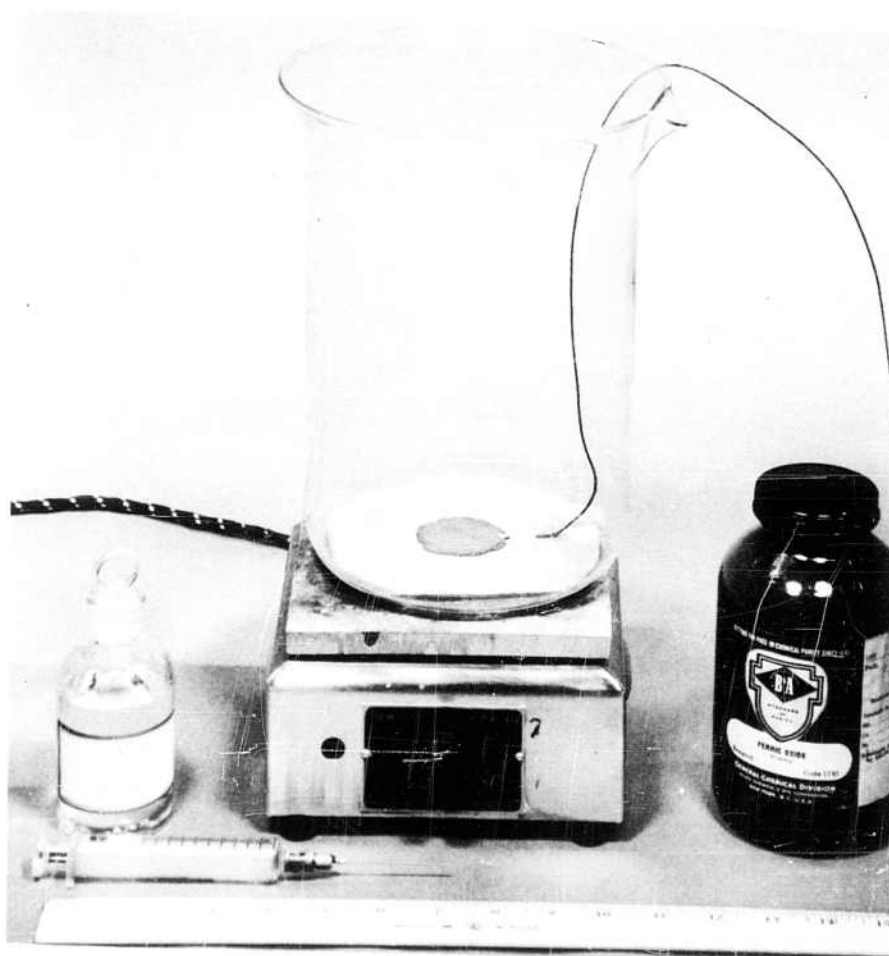


Figure 2. Fire Hazard Test Apparatus

The reagent-grade iron oxide ignited at 115°F in two of three attempts. Lowering the temperature to 110°F resulted in no ignition in two attempts.

Tests with the rusted steel band resulted in one ignition out of three attempts at 180°F, no ignition out of two attempts at 175°F, and two ignitions out of two attempts at 185°F.

On the basis of the foregoing tests, it is concluded that reagent-grade iron oxide and rusted metal at elevated temperatures (115° and 180°F, respectively) constitute a hazard with 50/50 fuel blend.

E. EFFECTS OF N_2O_4 ON METALS

1. Cobalt Alloys

Haynes Stellite 21 was tested on N_2O_4 at 65°F for 145 days with no adverse effect. The results are shown in Table 7.

2. Plating

Electroless nickel plating, 2 mils thick, on 1018 mild steel and 2014 aluminum alloy specimens was exposed to N_2O_4 at 65°F for 30 to 46 days. Table 7 shows the results of these tests. The plating was resistant to specification-grade N_2O_4 ; however, the plating is susceptible to attack by dilute nitric acid.

3. Effect of 70% Nitric Acid on Aluminum Alloy

Reference 7 states that corrosion products are formed when drops of 70% nitric acid are placed on 2014 aluminum alloy and allowed to stand open to the air, or closed and under nitrogen, for 7 days at room temperature. The resultant surface effect and corrosion phenomena experienced are shown in Figures 3 through 6. Corrosion results are shown in Table 8.

The aluminum alloy specimen open to the air had a mottled surface (after scrubbing with a rubber stopper under water), shallow intergranular attack to a depth of 0.05 mil (see Figure 5), and exhibited a weight increase. The aluminum alloy specimen in the closed system had a clean surface, shallow intergranular attack to a depth of 0.2 mil (see Figure 6), and a weight loss corresponding to 3 MPY.

The closed system is more detrimental to the aluminum alloy and, to remedy this situation, any residual nitric acid in a closed system must be purged with hot nitrogen gas (Reference 7).

TABLE 7
COMPATIBILITY OF METALS WITH N₂O₄ AT 65°F

Propellant Quantity: One fluid ounce per test tube.
Specimens: Rectangular coupons approximately 5 square inches in area.
Number of Specimens: Three per material in individual test tubes.
Condition: Partial immersion - static.
Apparatus: Pressure-tight, screw-top, aluminum-foil-gasketed, culture test tubes.
Data: Average of three specimens.

<u>Material</u>	<u>Time in Days</u>	<u>% Wt Change</u>	<u>Corrosion Rate-MPY</u>	<u>Rating^a</u>
<u>COBALT ALLOY</u>				
Haynes Stellite 21	145	+0.0024	—	A
<u>ELECTROLESS NICKEL PLATE</u>				
On 2014 Aluminum Alloy	46	-0.0226	0.023	A
On 1018 Steel Poppet	30	None	None	A
On 1018 Steel (Bent Bar)	30	-0.0253	0.025	A

a - Definitions of the ratings are given in Appendix A.

TABLE 8
COMPATIBILITY OF 2014 ALUMINUM ALLOY AND 70% HNO₃

Test Media - One drop of 70% HNO₃ on aluminum alloy specimen
Test Temperature - Ambient (70° to 80°F)

<u>Material</u>	<u>Time in Days</u>	<u>Test Conditions</u>	<u>%Wt Change</u>	<u>Corrosion Rate-MPY</u>	<u>Remarks</u>
2014 Aluminum Alloy (Pickled)	7	Open to Air	+0.0222	—	Salt formation
2014 Aluminum Alloy (Degreased)	7	Open to Air	+0.0125	—	Salt formation
2014 Aluminum Alloy (Pickled)	9	Sealed in Nitrogen	-0.1994	3.176	Salt formation

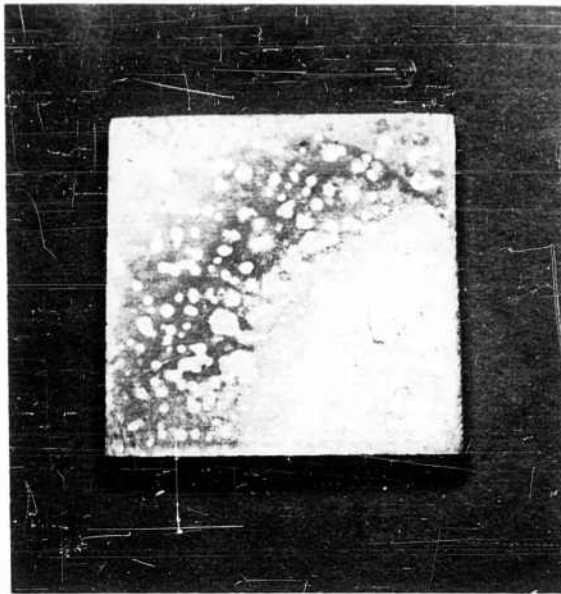


Figure 3. Effect of 70% Nitric Acid on 2014 Aluminum Alloy when Exposed to Air (Magnification 2X)

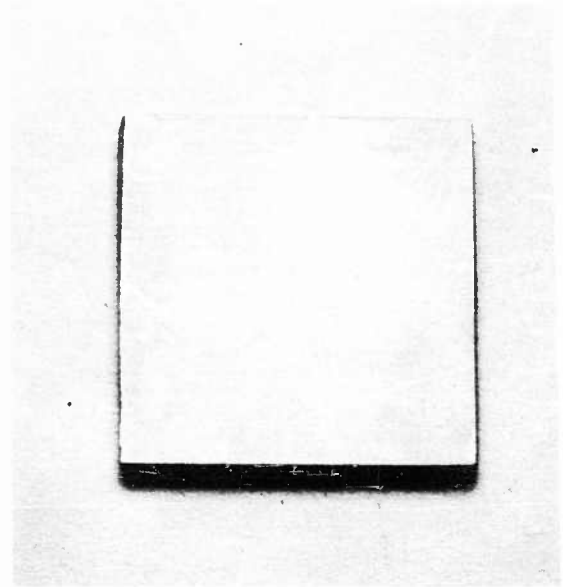


Figure 4. Effect of 70% Nitric Acid on 2014 Aluminum Alloy when Exposed to Nitrogen in a Closed Flask (Magnification 2X)

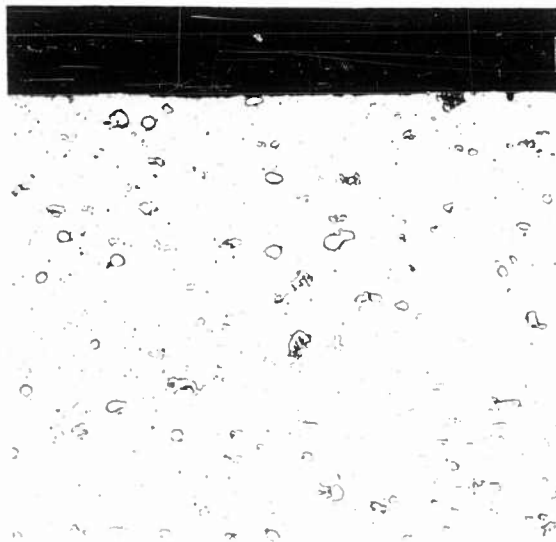


Figure 5. Surface Attack by 70% Nitric Acid on 2014 Aluminum Alloy when Exposed to Air (Magnification 500X)

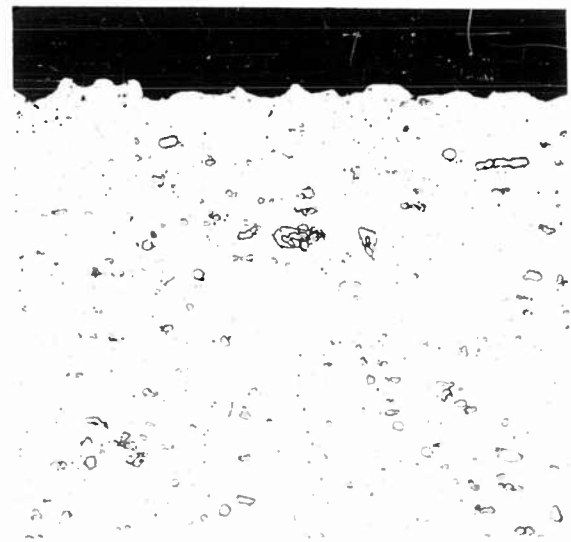


Figure 6. Surface Attack by 70% Nitric Acid on 2014 Aluminum Alloy when Exposed to Nitrogen in a Closed Flask (Magnification 500X)

F. EFFECTS OF N_2O_4 ON NONMETALS

1. Plastics

An intensive mechanical and physical property determination was made on samples of Teflons TFE 6 and TFE 7 after exposure to N_2O_4 at 65°F for 1, 3, 7, 14, and 30 days.

The specimens were characterized as follows:

- (1) Teflon 6C tubing - quenched to low density - Samples 3-2, 3-6, 4-2, and 4-5.
- (2) Teflon 6C tubing - annealed to high density - Samples 1-2, 2-2.
- (3) Teflon 7 sheet stock - Sample C - quenched
Sample C - annealed
- (4) Teflon 7 sheet stock - Samples 3, 4, 5A, 5B, and 6.

The results of the mechanical and physical properties are the average of three determinations as listed in Table 9.

There was a considerable spread in the tensile property values in the as-received condition on Teflon 7 sheet stock having a thickness of 1/4 and 1/16 inch. Figure 7 shows as a band the average range of the effect of N_2O_4 on the tensile strength of Teflons TFE 6 and TFE 7. Apparently, both Teflons initially lose tensile strength, but both recover by the end of the 30 days.

Elongation values decreased on the sheet stock of Teflon 7 and Teflon 6C high density; the Teflon 6C low-density samples, except 4-5, had an increase in elongation. However, there was no elongation value under 200%.

In general, the Shore Durometer Hardness values decreased for all the Teflons, before and after outgassing the N_2O_4 . The greatest spread was in the values obtained before outgassing. Figures 8 and 9 show as bands the average range of the effect of N_2O_4 on the hardness of Teflons TFE 6 and TFE 7, before and after outgassing N_2O_4 . Generally, the smaller the gage thickness, the greater the change in hardness. This is attributed to the limits of the test procedure for hardness measurements on thin stock.

The spread in hardness after outgassing was within limits of the classification requirements for an "A" or border-line "A" rating. See Appendix A of this report for definition of ratings.

The low weight and volume changes have shown that chemical and dimensional stability does exist with the Teflons tested.



TABLE 9

PROPERTIES OF TEFLON TFE 6 AND TFE 7 A

Sample	Sp. Gr.	Av. Thick (in.)	Hardness Shore D	1 DAY			Hardness Shore D	3 DAYS			Hardness Shore D
				Hardness Change	Wt Change (%)	Vol Change (%)		Hardness Change	Wt Change (%)	Vol Change (%)	
3 (TFE 7)	a	2.1475	0.08	63.7			63.7				63.7
	b			57.3	-6.4	+3.39	48.7	-15.0	+4.18	+5.37	53.7
	c			61.0	-2.7	+0.02	60.7	- 3.0	+0.01	0	60.0
4 (TFE 7)	a	2.1545	0.25	61.7			61.7				61.7
	b			62.3	+0.6	+1.27	54.3	- 7.4	+2.15	+1.72	58.0
	c			59.0	-2.7	+0.15	60.0	- 1.7	+0.36	+0.84	61.0
5A (TFE 7)	a	2.2043	0.09	64.0			64.0				64.0
	b			67.7	+3.7	+1.19	57.7	- 6.3	+2.21	+2.63	64.0
	c			62.7	-1.3	+0.14	62.0	- 2.0	+0.26	+0.06	61.7
5B (TFE 7)	a	2.2760	0.29	63.7			63.7				63.7
	b			69.0	+5.3	+0.37	61.0	- 2.7	+0.66	+1.08	64.3
	c			63.7	0	+0.07	62.0	- 1.7	+0.16	+0.22	61.0
6 (TFE 7)	a	2.1481	0.08	62.0			62.0				62.0
	b			60.3	-1.7	+3.46	47.3	-14.7	+4.16	+5.42	56.3
	c			60.3	-1.7	+0.03	60.0	- 2.0	+0.01	+1.12	60.0
C (TFE 7)	a	2.1470	0.07	62.0			62.0				62.0
	b			60.0	-2.0	+3.79	46.0	-16.0	+4.24	+6.04	55.0
	c			60.7	-1.3	+0.02	61.0	- 1.0	0	+0.95	60.3
D (TFE 7)	a	2.1910	0.09	64.0			64.0				64.0
	b			65.3	+1.3	+1.59	54.7	- 9.3	+2.61	+2.80	62.3
	c			62.0	-2.0	+0.17	62.0	- 2.0	+0.22	+0.03	61.3
1-2 (TFE 6)	a	2.2070	0.06	64.3			64.3				64.3
	b			66.0	+1.7	+1.89	53.3	-11.0	+2.68	+3.50	62.7
	c			65.0	+0.7	+0.11	63.0	- 1.3	+0.08	-0.49	61.3
2-2 (TFE 6)	a	2.2210	0.06	63.0			63.0				63.0
	b			64.7	+1.7	+1.63	54.0	- 9.0	+2.57	+2.43	63.0
	c			64.3	+1.3	+0.11	62.7	- 0.3	+0.10	-0.94	60.3
3-2 (TFE 6)	a	2.1470	0.06	59.3			59.3				59.3
	b			54.7	-4.6	+3.81	45.3	-14.0	+4.20	+2.59	51.0
	c			58.7	-0.6	+0.02	58.0	- 1.3	+0.01	-2.00	53.7
3-6 (TFE 6)	a	2.1500	0.06	60.7			60.7				60.7
	b			55.7	-5.0	+3.69	45.0	-15.7	+4.10	+4.28	53.0
	c			58.7	-2.0	+0.03	57.0	- 3.7	+0.02	-1.28	57.3
4-2 (TFE 6)	a	2.1450	0.06	58.3			58.3				58.3
	b			52.7	-5.6	+3.99	44.7	-13.6	+4.44	+3.63	49.0
	c			57.7	-0.6	+0.03	56.3	- 2.0	+0.03	-0.83	51.0
4-6 (TFE 6)	a	2.1450	0.06	58.7			58.7				58.7
	b			51.7	-7.0	+4.17	44.0	-14.7	+4.43	+3.30	49.7
	c			57.7	-1.0	+0.02	56.7	- 2.0	+0.03	-2.28	55.0

NOTES: a = original, b = before outgassing, c = after 10 day outgassing.

TABLE 9

TFE 6 AND TFE 7 AFTER EXPOSURE TO N_2O_4 AT $65^\circ F$

Vol Change (%)	Hardness Shore D	7 DAYS			Vol Change (%)	Hardness Shore D	14 DAYS			Vol Change (%)	Hardness Shore D	30 DAYS		
		Hardness Change	Wt Change (%)	Vol Change (%)			Hardness Change	Wt Change (%)	Vol Change (%)			Hardness Change	Wt Change (%)	Vol Change (%)
	63.7					63.7					63.7			
+5.37	53.7	-10.0	+3.81	+4.58	51.3	-12.4	+4.37	+5.02	51.3	-12.4	+4.39	+5.03		
0	60.0	- 3.7	+0.04	+0.16	63.0	- 0.7	+0.03	+0.66	59.7	- 4.0	+0.01	+1.03		
	61.7				61.7				61.7					
+1.72	58.0	- 3.7	+3.07	+3.33	54.3	- 7.4	+3.95	+3.74	54.0	- 7.7	+4.03	+3.68		
+0.84	61.0	- 0.7	+0.68	+1.05	61.3	- 0.4	+0.79	+0.17	57.0	- 4.7	+0.76	+0.63		
	64.0				64.0				64.0					
+2.63	64.0	0	+2.42	+3.24	61.7	- 2.3	+2.81	+1.88	58.7	- 5.3	+2.90	+3.19		
+0.06	61.7	- 2.3	+0.42	+0.78	64.0	0	+0.40	+0.44	60.7	- 3.3	+0.36	+0.61		
	63.7				63.7				63.7					
+1.08	64.3	+ 0.6	+0.86	+1.42	61.7	- 2.0	+0.95	+1.42	60.0	- 3.7	+1.84	+3.04		
+0.22	61.0	- 2.7	+0.35	-0.12	64.3	+ 0.6	+0.59	+0.61	58.3	- 5.4	+0.90	+1.51		
	62.0				62.0				62.0					
+5.42	56.3	- 5.7	+3.90	+4.86	55.3	- 6.7	+4.49	+4.92	50.7	-11.3	+4.32	+5.14		
+1.12	60.0	- 2.0	+0.02	-0.57	63.0	+ 1.0	+0.03	+0.71	58.7	- 3.3	+0.01	+0.58		
	62.0				62.0				62.0					
+6.04	55.0	- 7.0	+3.84	+4.50	56.0	- 6.0	+4.49	+7.74	50.3	-11.7	+4.41	+5.01		
+0.95	60.3	- 1.7	+0.03	+0.86	61.7	- 0.3	+0.03	+0.25	59.0	- 3.0	-0.01	+1.28		
	64.0				64.0				64.0					
+2.80	62.3	- 1.7	+2.65	+2.69	62.3	- 1.7	+3.25	+2.50	55.7	- 8.3	+3.13	+4.31		
+0.03	61.3	- 2.7	+0.24	-0.43	64.0	0	+0.28	+1.19	61.0	- 3.0	+0.24	+3.40		
	64.3				64.3				64.3					
+3.50	62.7	- 1.6	+2.44	+1.09	61.7	- 3.6	+3.12	+1.49	56.0	- 8.3	+3.00	+5.87		
-0.49	61.3	- 3.0	+0.11	-1.80	63.0	- 1.0	+0.12	-1.52	61.0	- 3.3	+0.10	+2.95		
	63.0				63.0				63.0					
+2.43	63.0	0	+2.26	+1.69	62.0	- 1.0	+2.97	+2.03	55.0	- 8.0	+2.91	+6.04		
-0.94	60.3	- 2.7	+0.13	+1.51	63.0	0	+0.13	-0.48	61.7	- 1.3	+0.07	+2.32		
	59.3				59.3				59.3					
+2.59	51.0	- 8.3	+3.98	+2.61	52.0	- 7.3	+4.57	+3.79	47.3	-12.0	+4.31	+8.52		
-2.00	53.7	- 5.6	+0.03	-2.82	59.0	- 0.3	+0.04	-0.77	58.3	- 1.0	+0.02	+7.76		
	60.7				60.7				60.7					
+4.28	53.0	- 7.7	+3.78	+2.58	53.0	- 7.7	+4.70	+4.60	46.0	-14.7	+4.34	+1.23		
-1.28	57.3	- 3.4	+0.02	-1.89	59.0	- 1.7	+0.03	-0.54	55.3	- 5.4	+0.01	-2.81		
	58.3				58.3				58.3					
+3.63	49.0	- 9.3	+3.71	+3.59	49.0	- 9.3	+4.83	+3.67	46.0	-12.3	+4.24	+0.65		
-0.83	51.0	- 7.3	0	-1.20	55.7	- 2.6	+0.03	-0.56	56.0	- 2.3	+0.02	-3.92		
	58.7				58.7				58.7					
+3.30	49.7	- 9.0	+3.76	+2.50	50.3	- 8.4	+4.75	+4.86	45.0	-13.7	+4.52	+2.96		
-2.28	55.0	- 3.7	+0.02	-2.23	58.3	- 0.4	+0.01	-0.24	57.0	- 1.7	+0.01	-1.90		

1

TABLE 9 (CONT)
 PROPERTIES OF TEFLON TFE 6 AND TFE 7 AFTER EXPOSURE TO N

Sample		Sp. Gr.	Av. Thick (in.)	1 DAY			3 DAYS				7 DAYS				Tensile Change (%)
				Tensile (psi)	Tensile Change (%)	Elong. (%)	Tensile (psi)	Tensile Change (%)	Elong. (%)	Elong. Change (%)	Tensile (psi)	Tensile Change (%)	Elong. (%)	Elong. Change (%)	
3 (TFE 7)	a	2.1475	0.08	3932		258	3932		258		3932		258		
	b			3525	-10.4	278	3947	+ 0.38	272	+ 5.4	2981	-24.2	313	+21.3	3669 - 6
4 (TFE 7)	a	2.1545	0.25	4198		366	4198		366		4198		366		
	b			3270	-22.1	233	3613	-13.9	230	-37.2	2852	-32.1	290	-20.8	3090 -26
5A (TFE 7)	a	2.2043	0.09	3747		358	3747		358		3747		358		
	b			3712	- 0.93	277	3855	+ 2.88	271	-24.3	3104	-17.2	450	+25.7	3737 - 0
5B (TFE 7)	a	2.2760	0.29	3453		296	3453		296		3453		296		
	b			2949	-14.6	290	3296	- 4.54	307	+ 3.7	2206	-36.1	396	+33.8	2720 -21
6 (TFE 7)	a	2.1481	0.08	4785		361	4785		361		4785		361		
	b			3297	-31.1	290	3052	-36.2	245	-32.1	3491	-27.0	441	+22.2	3438 -28
C (TFE 7)	a	2.1470	0.07	5007		358	5007		358		5007		358		
	b			3960	-20.9	258	3735	-25.4	310	-13.4	3797	-24.2	427	+19.3	3485 -30
D (TFE 7)	a	2.1910	0.09	3911		425	3911		425		3911		425		
	b			4701	+20.2	247	4442	+13.6	282	-33.7	3180	-18.7	417	- 1.9	3582 - 8
1-2 (TFE 6)	a	2.2070	0.06	3516		378	3516		378		3516		373		
	b			4193	+19.3	253	4000	+13.8	264	-30.2	3147	-16.5	350	- 7.4	4258 +21
2-2 (TFE 6)	a	2.2210	0.06	3061		454	3061		454		3061		454		
	b			3653	+19.3	291	3352	+ 9.54	328	-27.8	2881	- 5.88	483	+ 6.4	4117 +34
3-2 (TFE 6)	a	2.1470	0.06	3860		431	3860		431		3860		431		
	b			3274	-15.2	518	3077	-20.3	521	+20.9	2966	-23.2	485	+12.5	3378 -12
3-6 (TFE 6)	a	2.1500	0.06	3516		405	3516		405		3516		405		
	b			2894	-17.7	477	3133	-10.9	524	+29.4	2567	-27.0	452	+11.6	3099 -11
4-2 (TFE 6)	a	2.1450	0.06	3914		291	3914		291		3914		291		
	b			3199	-18.3	307	3502	-10.5	331	+13.8	3123	-20.2	324	+11.3	3346 -14
4-5 (TFE 6)	a	2.1450	0.06	4195		312	4195		312		4195		312		
	b			3619	-13.7	309	3188	-24.0	296	- 5.1	3352	-20.1	343	+ 9.9	3441 -18

NOTES: a = original, b = before outgassing.

TABLE 9 (CONT)

PROPERTIES OF TEFLON TFE 6 AND TFE 7 AFTER EXPOSURE TO N_2O_4 AT 65°F

	3 DAYS			7 DAYS			14 DAYS			30 DAYS		
	Tensile Change (%)	Elong. Change (%)	Tensile (psi)	Tensile Change (%)	Elong. Change (%)	Tensile Change (%)	Tensile (psi)	Tensile Change (%)	Elong. Change (%)	Tensile Change (%)	Elong. Change (%)	Tensile (psi)
1												
2	+ 0.38	258 272	+ 5.4	3932 2981	258 313	+21.3	3932 3669	- 6.69	258 281	+ 8.9		3932 3813
3												
4	-13.9	366 230	-37.2	4198 2852	366 290	-20.8	4198 3090	-26.4	366 259	-29.2		4198 3291
5												
6	+ 2.88	358 271	-24.3	3747 3104	358 450	+25.7	3747 3737	- 0.27	358 348	- 2.8		3747 3814
7												
8	- 4.54	296 307	+ 3.7	3453 2206	296 396	+33.8	3453 2720	-21.2	296 334	+12.8		3453 3291
9												
10	-36.2	361 245	-32.1	4785 3491	361 441	+22.2	4785 3438	-28.2	361 333	- 7.8		4785 3068
11												
12	-25.4	358 310	-13.4	5007 3797	358 427	+19.3	5007 3485	-30.4	358 326	- 8.9		5007 3921
13												
14	+13.6	425 282	-33.7	3911 3180	425 417	- 1.9	3911 3582	- 8.41	425 302	-28.9		3911 4345
15												
16	-13.8	378 264	-30.2	3516 3147	378 350	- 7.4	3516 4258	+21.1	378 228	- 4.0		3516 4964
17												
18	+ 9.54	454 328	-27.8	3061 2881	454 483	+ 6.4	3061 4117	+34.5	454 271	-40.3		3061 4087
19												
20	-20.3	431 521	+20.9	3860 2966	431 485	+12.5	3860 3378	-12.5	431 485	+12.5		3860 3279
21												
22	-10.9	405 524	+29.4	3516 2567	405 452	+11.6	3516 3099	-11.9	405 493	+20.5		3516 3021
23												
24	-10.5	291 331	+13.8	3914 3123	291 324	+11.3	3914 3346	-14.5	291 273	- 6.2		3914 3603
25												
26	-24.0	312 296	- 5.1	4195 3352	312 343	+ 9.9	4195 3441	-18.0	312 251	-19.6		4195 3518

2

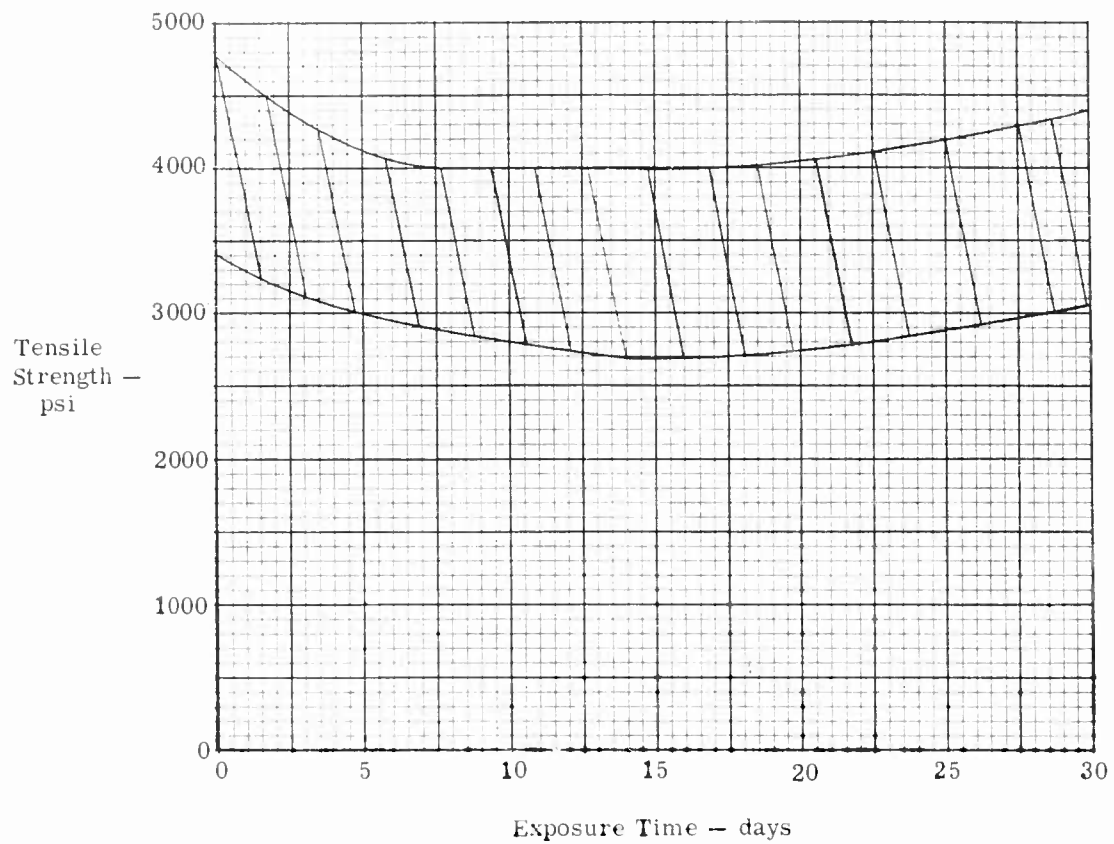


Figure 7. Effects of N_2O_4 on Tensile Strength of Teflon TFE 6 and TFE 7 (Before Outgassing N_2O_4)

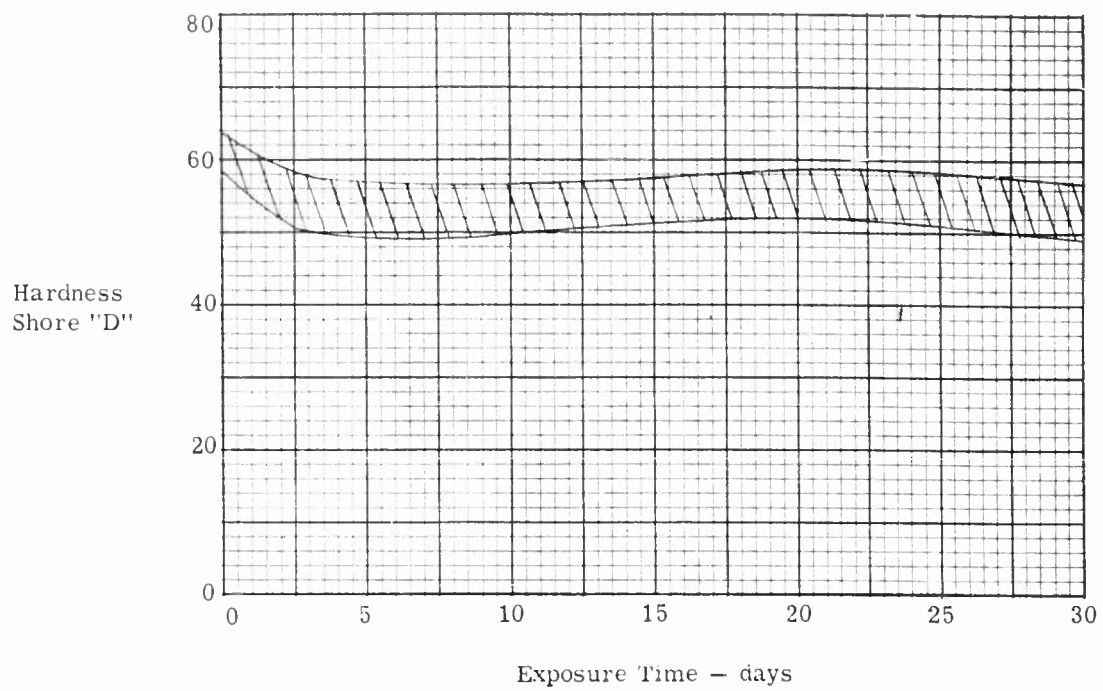


Figure 8. Effects of N_2O_4 on Hardness of Teflon TFE 6 (Before and After Outgassing)

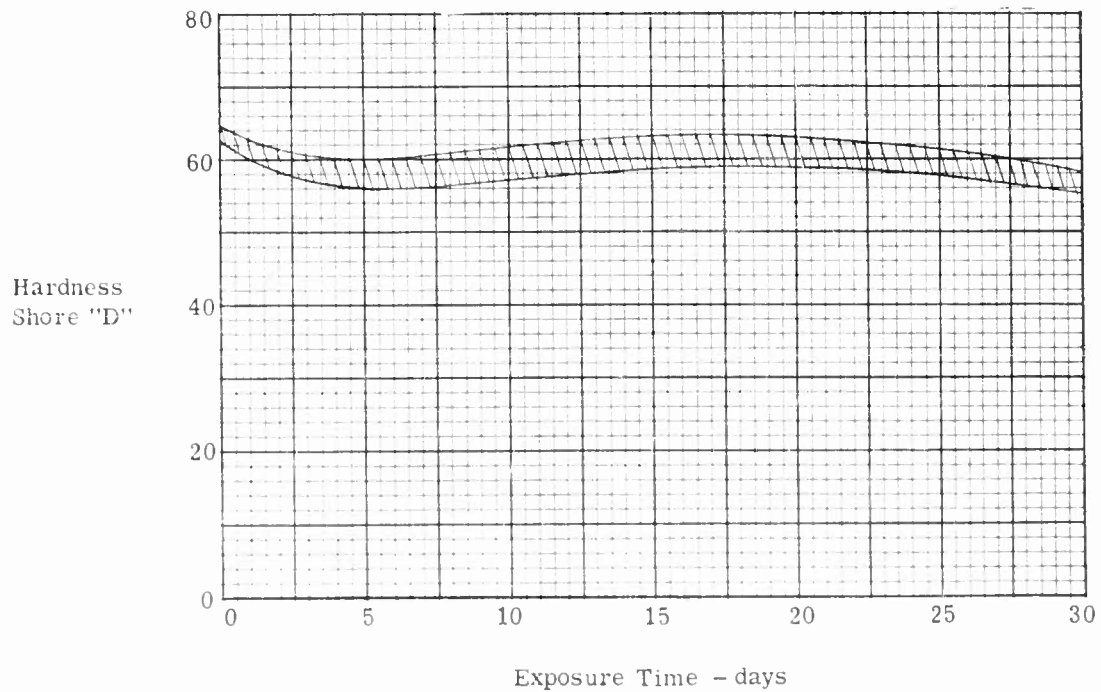


Figure 9. Effects of N_2O_4 on Hardness of Teflon TFE 7 (Before and After Outgassing)

The volume changes before and after outgassing are within the classification limits of an "A" rating or a border-line "A" rating.

A cross-linked polyethylene, formulation 39, obtained from ASD, showed a decided reduction in elongation, but otherwise resistant to N_2O_4 at 65°F for 30 days (see Table 10).

Aclar 191, a fluorohalocarbon, showed good resistance to N_2O_4 for 30 days; Capran 391, a polyamide, dissolved on contact with N_2O_4 . These were screening tests.

Amerplate, a polyvinylchloride, was found compatible with N_2O_4 at 65°F for 22 days. This was a screening test and only visual examinations were made (see Table 10).

2. Elastomers

Ten ethylene-propylene rubber compounds, formulated from the Montecatini Company base copolymer by Seals East Orange, Inc., and one rubber compound (formula 132) formulated from Hercules Powder Company base copolymer by Thiokol Chemical Corporation were incompatible with N_2O_4 at 65°F (see Table 10).

3. Paints and Coatings

Several paints were tested for resistance to N_2O_4 (see Table 11). Mild steel specimens were coated with the paints per vendor specifications and were exposed to N_2O_4 splash tests similar to a procedure outlined in Reference 6. Briefly, the procedure consists of immersing the coated specimen in the N_2O_4 at 55° ± 3°F for one minute and then allowing the specimen to air dry for 24 hours at 80° ± 3°F and a relative humidity no greater than 80%. Only Proseal 333 was unaffected by the splash and drip tests with N_2O_4 . For the drip test, N_2O_4 was allowed to drip for 2 hours at an approximate rate of 1 cc per minute on a coated specimen partly immersed in water. Also, the Proseal 333 was unaffected after being immersed in N_2O_4 at 55°F for 5 weeks.

Rezklad 1, 2, and 3 (epoxy concrete coatings) were exposed to N_2O_4 splash, drip, and total immersion tests. The results are shown in Table 11. Only slight discoloration was noted for each material after the splash tests. For the drip test, the N_2O_4 was allowed to drip for 2 hours. At the end of this time, the surface of each material exposed to the drippings partly washed away. A maximum depth of approximately 0.05 inch was noted for Rezklad 2 and 3; for Rezklad 1, a depth of 0.005 inch was noted. Each compound fell apart within 24 hours when totally immersed in N_2O_4 . These coatings offer no protection unless the N_2O_4 is washed off immediately after an N_2O_4 spill.

TABLE 10

COMPATIBILITY OF NONMETALS WITH N_2O_4 AT 65°F

Propellant Quantity:		One fluid ounce per test tube.														
Specimens:		ASTM D1457-56T die tensile bars or rectangular bars.														
Number of Specimens:		Three per material in individual test tubes.														
Condition:		Full immersion - static.														
Apparatus:		Pressure-tight, screw-top, aluminum-foil-gasketed, culture test tubes.														
Data:		Average of three specimens.														
Material	Time In Days	Control			Before			After			Remarks					
		Shore Hardness	Tensile Ksi	% Elong.	Shore Hardness	Tensile Ksi	% Elong.	% Wt Change	% Vol Change	% Wt Change		% Vol Change	Rating ^a			
PLASTICS																
Formulation 39	30	52D	1.94	312	52D	1.23	45	+18.0	+8.17	+5.26	+1.11	A	Decrease in elongation 1-2 mils thick			
Aclar 191	30	-	-	-	-	-	-	+6.70	+4.66	-	-	-	A	Dissolves on contact 1-2 mils thick		
Capran 391	-	-	-	-	-	-	-	-	-	-	-	-	D	No visual change		
Amerplate	22	-	-	-	-	-	-	-	-	-	-	-	A	Specimens dissolved		
ETHYLENE-PROPYLENE RUBBERS																
X7000-1 thru -7 and -9 thru -11	18	-	-	-	-	-	-	-	-	-	-	-	D	Fell apart on handling		
Formulation 132	30	-	-	-	-	-	-	-	-	-	-	-	D			
GRAPHITES																
Graphitar 14	30	-	-	-	-	-	-	+0.83	+7.87	+0.18	-	-	A			
Graphitar 39	30	-	-	-	-	-	-	+0.37	+6.37	+0.08	-	-	A			
Graphitar 86	30	-	-	-	-	-	-	+2.46	+6.24	+1.90	-	-	A			
CCP-72	30	-	-	-	-	-	-	+1.60	0	+0.84	-	-	A			
LUBRICANT																
PD 788	1	-	-	-	-	-	-	-	-	-	-	-	D	Washed off and left powdered residue		

^a - Definition of ratings are given in Appendix A.

TABLE 11
SPLASH AND DRIP TESTS WITH N_2O_4

<u>Material</u>	<u>Splash Test</u>	<u>Drip Test</u>	<u>Rating^a</u>
Proseal 333	Coating Unaffected	Coating Unaffected (2 hours)	A
Markal DA-8 Aluminum	Blistered Badly	- - -	D
Markal DA-8 Gray	Blistered Badly	- - -	D
Markal DA-9 Aluminum	Blistered Slightly	- - -	C
Aluminous Paint	Blistered Badly	- - -	D
Rezklad (Epoxy Concrete Coating)			
1 Regular	Slight Discoloration	Binder Washed Away to Depth of 0.005 inch in 1.5 hours	B
2 Special Surfacer	Slight Discoloration	Binder Washed Away to Depth of 0.05 inch in 1.5 hours	B
3 Chemical Resistance	Slight Discoloration	Binder Washed Away to Depth of 0.05 inch in 1.5 hours	B

a - Definitions of ratings are given in Appendix A.

4. Lubricants

A fluorocarbon lubricant (PD 788) was exposed to N_2O_4 liquid and vapor at 65°F. The grease washed off and left a powdered residue in N_2O_4 (see Table 10).

5. Graphites

Four carbon-graphite materials used as bearings and seals were immersed in N_2O_4 at 65°F for 30 days and were found resistant. The test results are shown in Table 10.

6. Permeability Tests

Permeability tests were performed with Teflon FEP and Teflon TFE 7 to compare the transmission rates of each material when exposed to N_2O_4 . Teflon 7 is the least porous of the TFE series; Teflon FEP, a fluorinated ethylene-propylene copolymer, is known to be less porous than Teflon TFE.

The test procedure used during these tests was based upon an ASTM procedure, D1434-58. The test apparatus shown in Figure 10, was modified to fill the requirements of the propellant with respect to compatible materials.

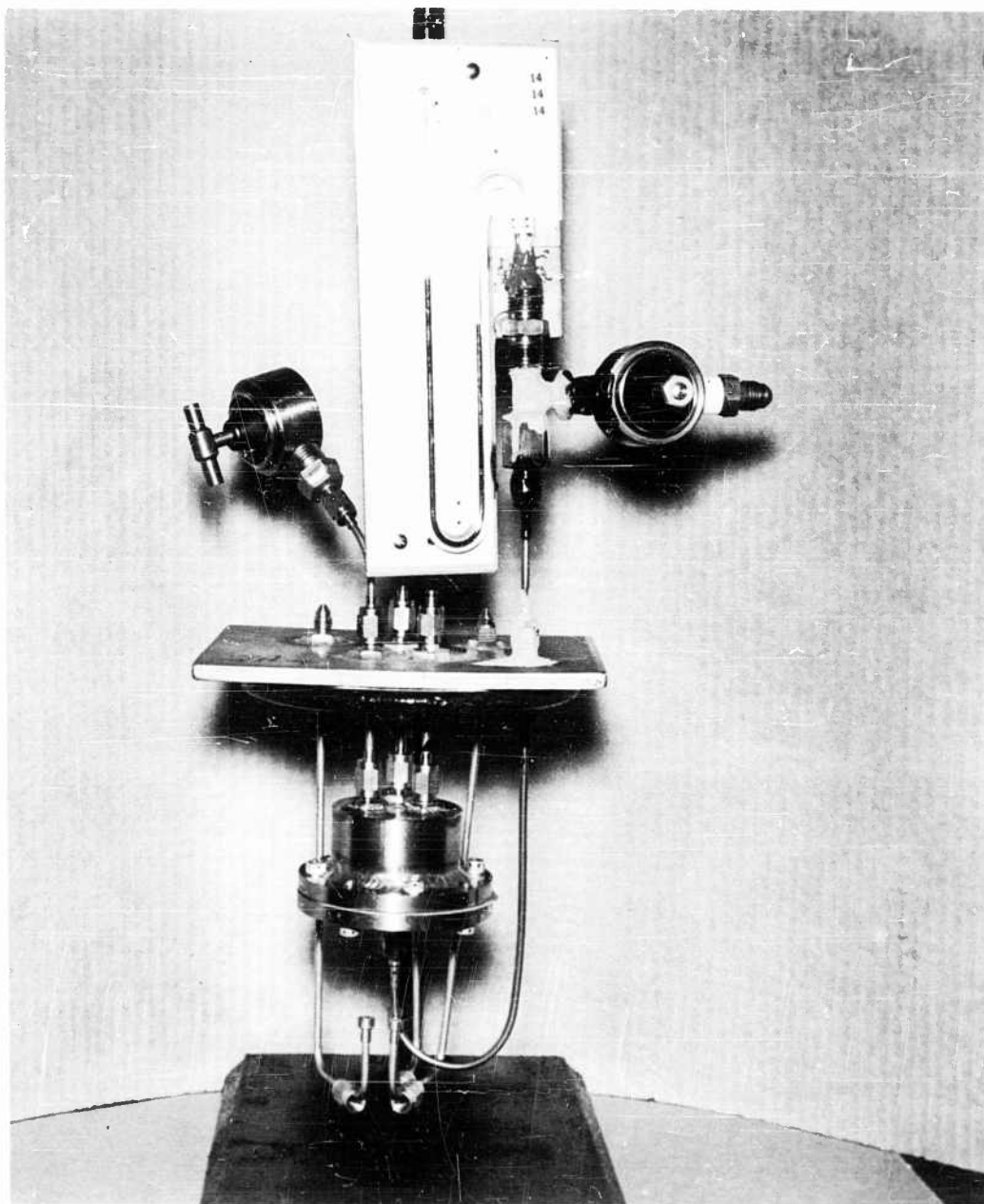


Figure 10. Apparatus for Measuring Permeability Rates of N_2O_4 through Teflon

The Teflon samples were 10-mil-thick sheets milled from bar stock. The test specimen, 3 inches in diameter, was placed between two chambers, one of which contained the N_2O_4 . A vacuum was drawn on the remaining chamber of known volume. A differential pressure was thus provided across the membrane causing the permeation to proceed in one direction. The change in pressure per unit time in the vacuum chamber was measured by a mercury manometer. The surface area of the specimens was 2.4 square inches. The data obtained at room temperature was corrected to $0^\circ C$ ($32^\circ F$) and was extrapolated as a transmission rate for 100 square inches per 24 hours. Gas transmission is the product of the diffusion rate and solubility of the test gas in the specimen. It is generally acquired after a stationary concentration gradient of the test gas is obtained in the specimen provided that the loss of water or volatiles originally present in the specimen is negligible.

The transmission rates were obtained for air at one atmosphere differential pressure and for N_2O_4 at 16 to 17 psia differential pressure. The results shown in Table 12 indicate that, although there is relatively no difference between the air transmission rates with both Teflons, Teflon 7 permeates approximately three times more N_2O_4 than Teflon FEP.

7. Dynamic Seal Tests

A dynamic seal tester was fabricated to evaluate O-ring type seals during exposure to N_2O_4 . This tester is illustrated in Reference 7. The tester consists of a cylinder of approximately 2 inches internal diameter with a piston located in the center of a shaft. The shaft, which extends out of the ends of the cylinder, was sealed at either end with the two O-ring seals to be tested. The piston was also adapted with two O-ring seals.

A hole was drilled in the center of the shaft; this hole was continuous with a hole drilled between the piston seals. This served to determine if the piston seals were leaking during the test. All wearing surfaces had an RMS finish of 8 or better. The shaft was chrome-plated.

The cylinder was filled with N_2O_4 by means of a reservoir and a bypass line. The linkage between the motor and tester was fitted with a strain gage feeding a signal to a pen recorder. The calibrated strain gage permits a recording of the force required to move the piston. The data was recorded for one minute every eight minutes. Each test was run for approximately 1000 cycles. The interpretation of the data acquired was based upon the change in force required to move the piston during the test, the force required to move the piston after having set idle for several hours (break-away force), and the condition of the shaft and O-ring seals after the test.

Three O-rings were evaluated: Omniseals and Bal Seals; Teflon covered stainless steel springs; and a resin-cured butyl rubber, formulation 121, obtained from ASD. The results of these tests are shown in Figure 11 as a plot of force versus cycles.

TABLE 12
PERMEABILITY DATA FOR TEFLON TFE 7 AND TEFLON FEP

Specimen	Thickness (Mils)	Density at 82° F (gm/cc)	Transmission Rate (cc/100 in ² /24 hr)	
			Air	N ₂ O ₄
TFE 7	10.0	2.186	20.0	275.9
FEP	10.6	2.138	30.0	81.8

The Omniseal test at atmospheric pressure required a different force to move the piston in each direction. This was probably due to loading techniques. Toward the end of the test, the recording became erratic due to a broken strain gage. The break-away force was about 30% greater than the force required to move the piston during the test. No leakage occurred during or after the test. All O-ring seals appeared worn on the sealing edges. Loading the seals was difficult due to the close tolerance required. Prior to the high-pressure run (100 psig), the shaft O-ring seals were provided with "shoe-horn" type fit to ensure against distortion during mounting.

New Omniseals were used for the high-pressure test. The apparatus was provided for application of constant nitrogen pressure during the test. With the new fitting of the shaft seals, the force required to move the shaft was less than the previous test. The break-away force was approximately 30% more than the force required to move the piston during the test. Leakage occurred through one seal on the piston during the test. All O-ring seals appeared slightly worn, but in good condition except for the one seal on the piston. This seal had thin, extruded, teeth-like protrusions. This probably occurred during assembly of piston to cylinder.

The Bal Seals required little force to move the piston. They sealed adequately at atmospheric pressures. The break-away force was the same as the force used to move the piston during the test. Examination of the seals after testing indicated that a piston seal had an area where the spring had worn through the sealing lip of the O-ring.

In an attempt to run at higher pressure, the seals leaked above 30 psig. Therefore, the test was terminated.

During these dynamic seal tests, the chrome-plated stainless steel shaft showed no signs of being adversely affected.

A high-pressure dynamic seal test with the resin-cured butyl rubber O-rings (Formulation 121), lubricated with Nordcoseal 147S, was conducted in a similar tester specifically designed for rubber O-ring use. After 2 hours of cycling at 100 psig, the force increased with time and

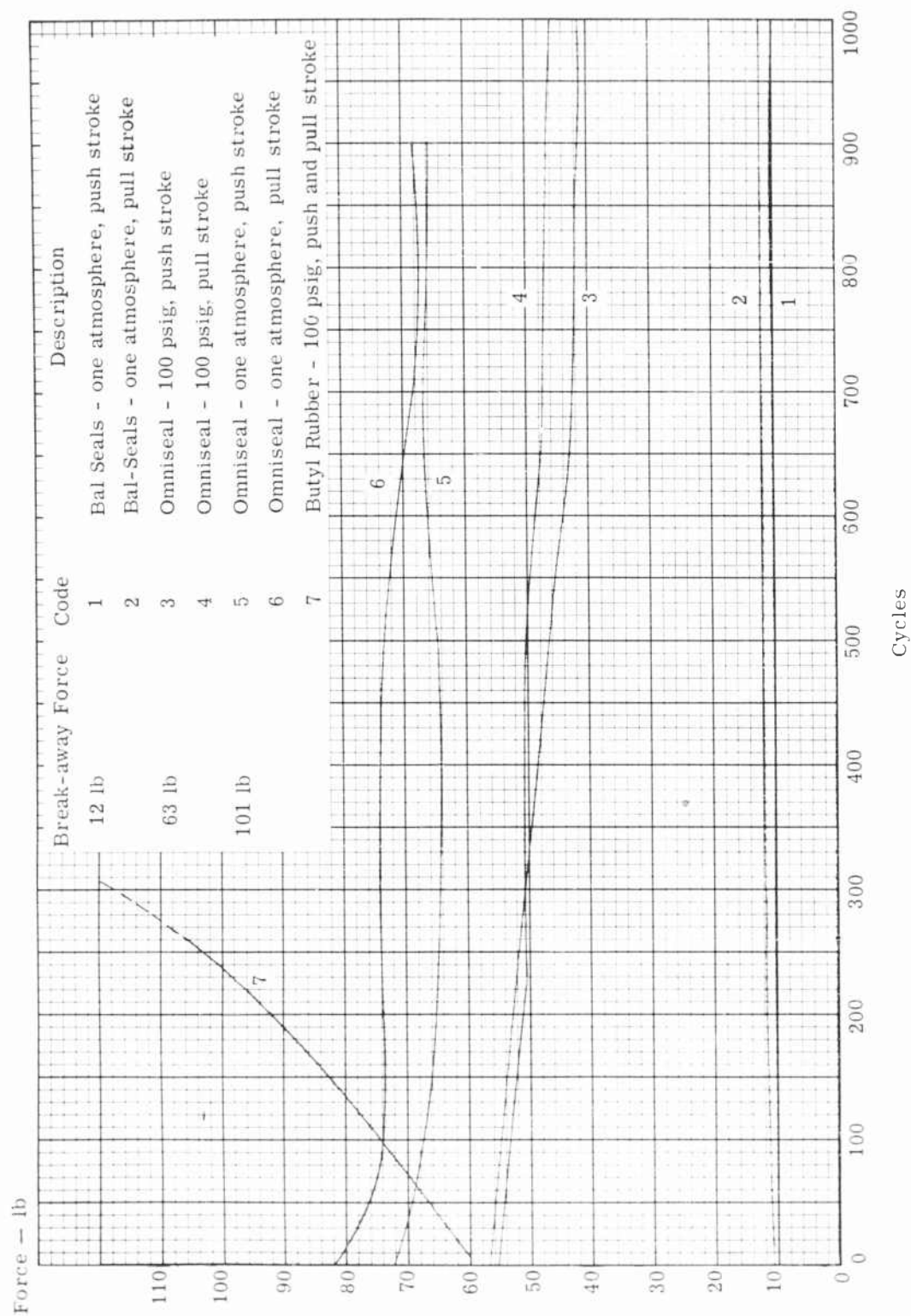


Figure 11. Dynamic Seal Test Results

eventually exceeded the capacity of the strain gage. Inspection of the O-rings after test showed that the lubricant had washed away and that the O-rings were soft, tacky, and swollen. Under static conditions and total immersion in N_2O_4 at 65°F for 30 days, this material had swollen 48% before outgassing (Reference 7).

The Omniseals O-rings were adequate for dynamic sealing at system working pressures up to 100 pounds. Although one piston seal leaked during test, a slight modification of the test unit should provide for easier mounting of these seals so that even higher pressure sealing may be attained. This seal should be further tested to determine maximum system pressure usage.

G. FIRE HAZARDS OF MATERIALS EXPOSED TO N_2O_4

1. Liquids

Fire hazard tests were conducted at room temperature and at one atmosphere with various liquids exposed to drops of N_2O_4 . The procedure used differed from similar tests with the fuel blend only in that a 3-inch-diameter watchglass was used to contain the liquid to be tested and that the N_2O_4 was delivered from a sealed stainless steel container through Teflon tubing. Approximately 2 to 3cc of N_2O_4 were dripped on the test samples. Liquids which showed any indication of reaction were tested further. The first test consisted of dripping N_2O_4 on the surface of the liquid sample contained in a small cylindrical glass container 2.5 inches long and 1 inch in diameter. A second test consisted of introducing the N_2O_4 beneath the surface of the liquid. Finally, a sample of isopropyl alcohol was heated to 120°F prior to the addition of N_2O_4 . Temperature increases were measured with a mercury thermometer.

The results of these tests are shown in Table 13. Of the liquids tested, only the 50/50 fuel blend and aniline ignited.

2. Solids

Fire hazard tests were conducted at room temperature and at one atmosphere with various solids exposed to drops of N_2O_4 . The procedure was similar to that used for liquids in the foregoing. After dripping N_2O_4 on the specimen, observations were made during a minimum period of one hour. In addition to the drip tests, certain solids were soaked in liquid N_2O_4 for 20 seconds and then allowed to gas off for a minimum time of one hour on a 3-inch-diameter watchglass. The results of these tests also are reported in Table 13. Of the solids tested, masking tape ignited after drip and soak tests with ignition occurring sooner after the drip test. Five rubber gloves were tested and only two ignited. The Davol latex glove ignited after the drip and soak tests with ignition occurring sooner after the soak test; Ebonettes ignited after the soak test, but not after the drip test.

Similar tests are recommended for all materials where information is lacking on the fire hazard potential of the material when used in areas where N_2O_4 spills may occur.

TABLE 13
FIRE HAZARD TESTS OF MATERIALS EXPOSED TO N_2O_4

Material	Observations	
<u>LIQUIDS</u>		
Acetone	No ignition, acetone turned green, 80° F rise when N ₂ O ₄ added below surface	
Aniline	Ignition preceeded by popping and sparking	
Benzene	No ignition, 5° F rise when N ₂ O ₄ added below surface	
50/50 Fuel Blend	Immediate audible report with ignition	
Isopropyl Alcohol	No ignition even when heated to 120° F prior to dripping N ₂ O ₄ , 60° F rise when N ₂ O ₄ added below and on surface	
Kel-F Fluorocarbon Oil 3	No ignition	
Methyl Alcohol	No ignition, 5° F rise when N ₂ O ₄ added below surface	
Motor Oil (SAE10)	No ignition, slight foaming	
Penetrating Oil	No ignition, discolored	
Red Hydraulic Oil (MIL-H-5606A)	No ignition, darkened	
Silicone Oil SF77	No ignition	
Trichloroethylene	No ignition	
<u>SOLIDS</u>		
	<u>Soak Test</u>	<u>Drip Test</u>
Asphalt	No ignition	No ignition, softened
Blotter		No ignition
Cadmium (mossy)		No ignition
Cardboard	No ignition	No ignition
Cotton Cloth		No ignition
Dust		No ignition
Dacron Yarn	No ignition	No ignition, dissolved
Fairprene Cloth (Neoprene 0.01 inch thick)	No ignition	No ignition, hardened

TABLE 13 (CONT)
FIRE HAZARD TESTS OF MATERIALS EXPOSED TO N₂O₄

Material	Observations	
<u>SOLIDS (CONT)</u>	<u>Soak Test</u>	<u>Drip Test</u>
Grass (dry)		No ignition, bleached
Leather	No ignition	No ignition, softened
Leaves		No ignition, bleached
Magnesium (turnings)		No ignition
Mohair		No ignition
Molykote G		No ignition
Mylar	No ignition	No ignition, softened
Nylon Cloth	No ignition	No ignition, dissolved
Nylon Yarn		No ignition, dissolved
Orlon Yarn		No ignition
Paper		No ignition
Rags (oily)		No ignition
Rayon (taffeta)	No ignition	No ignition, dissolved
Rubber Gloves (surgical)		
Latex Seamless Standard (0.008 in.)		No ignition
Amber Plus (0.013 in.)		No ignition, hardened
National Glove No. 200 (0.018 in.)		No ignition, hardened and became brittle
Davol Latex (0.008 in.)	Ignition in 75 sec	Ignition in 160 sec
Ebonettes (0.013 to 0.015 in.)	Ignition in 90 sec	No ignition
Sawdust		No ignition, darkened
Silk Cloth		No ignition, bleached
Silk Cloth (Hong Kong)		No ignition
Styrene (Styrofoam)	No ignition	No ignition, dissolved
Tape (Masking)	Ignition in 120 sec	Ignition in 15 to 20 sec
Tobacco		No ignition
Vermiculite		No ignition
Wool		No ignition, bleached

SECTION IV

PROPELLANT HANDLING

A. MIXING OF 50/50 FUEL BLEND

The feasibility of mixing the N_2H_4 and UDMH by diffusion was determined using a 1cc Beckman silica absorption cell (2.0 to 3.0cc capacity). This was a repeat test identical with the one described in Reference 3. The UDMH was added to the absorption cell which was fitted with an upper cell containing N_2H_4 . After 28 days, spectral analysis indicated that complete mixing had been accomplished. Diffusion is not recommended for mixing the fuel blend.

B. STORAGE OF 50/50 FUEL BLEND AT $60^\circ \pm 5^\circ F$

A storage test was completed at simulated silo temperature ($60^\circ \pm 5^\circ F$) for 15 months. This test consisted of storing the fuel blend in a sealed two-quart-capacity 1100 aluminum alloy tank along with a second container of glass. A complete description of the test is given in Reference 1.

Vapor and liquid samples from each container were obtained and analyzed spectrophotometrically. Vapor samples were taken monthly and were subjected to infrared analysis. The results of these analyses indicate only trace amounts of ammonia identical with the initial vapor analysis showing no appreciable decomposition. A liquid sample was taken at the start and at the end of the storage test and were analyzed with a Beckman DK-1 near-infrared spectrophotometer, using the procedure described in Reference 3. Analysis of the liquid samples at the start and the end of test are shown in Table 14. Although these results show some decrease of the UDMH concentration, they indicate no decomposition difference due to container material. The change in the UDMH content from the start to the end of test may be attributed in part to experimental error in spectral analysis and in part to loss of UDMH vapors at sampling periods during storage. The experimental error in the spectral analysis at the beginning of this program was found to be $\pm 0.5\%$ for UDMH. Improvements in the procedure and technique resulting from the analysis of a large number of samples, and obtaining highly purified UDMH and N_2H_4 as standards, have reduced this error to $\pm 0.2\%$ for UDMH. The accuracy for the N_2H_4 remained at $\pm 0.2\%$.

As further evidence that no appreciable decomposition of the fuel blend occurred, pressures monitored throughout the test period showed no significant build-up. In addition, samples of the liquid subjected to drop weight tests gave negative results. These results were reported in Section II, Physical Properties of Fuel Blend. Finally, the color of the fuel blend was unchanged.

TABLE 14

50/50 FUEL BLEND ANALYSIS FOR STORAGE TEST AT 60° ±5°F

Fuel Blend Composition	Start Wt %	After 15 Months Wt %	
		Glass Tank	1100 AlAl Tank
UDMH	48.7	47.4	47.4
N ₂ H ₄	50.4	50.6	50.5
H ₂ O + Total Impurities	0.9 ^a	2.0	2.1

a - Inaccuracy of spectral method at start of program

A second test was also completed with the fuel blend stored in a sealed glass bottle at 60° ±5°F for a period of 12 months. This test was conducted to determine if the fuel blend would separate during long-term storage. Analysis of the fuel blend at the start and end of test (of samples taken from the top, middle, and bottom of the glass bottle) are shown in Table 15. These results show that the fuel blend did not separate during storage. The difference in analyses from the start of the test to the end is attributed to experimental error in spectral analysis.

TABLE 15

50/50 FUEL BLEND ANALYSIS FOR SEPARATION TEST AT 60° ±5°F

Fuel Blend Composition	Start Wt %			After 12 Months Wt %		
	Top	Middle	Bottom	Top	Middle	Bottom
UDMH	48.0	47.8	47.8	48.8	48.6	48.6
N ₂ H ₄	49.8	49.4	49.7	49.2	49.4	49.2
H ₂ O + Total Impurities	2.2	2.8	2.5	2.0	2.0	2.0

SECTION V
FLAMMABILITY CHARACTERISTICS OF 50/50 FUEL
BLEND - N_2O_4 - AIR - WATER MIXTURES

The presence of small quantities of water vapor affects the flammability characteristics of some materials (Reference 8). In view of this, the U. S. Bureau of Mines performed a study to determine the effects of water on the flammability characteristics of the 50/50 fuel blend in N_2O_4 and air atmospheres (Reference 9).

A. SPONTANEOUS IGNITION CHARACTERISTICS OF 50/50 FUEL BLEND - WATER IN VARIOUS N_2O_4 - AIR MIXTURES

As noted in a previous report (Reference 10), N_2H_4 , UDMH, and the 50/50 fuel blend react spontaneously with atmospheres containing N_2O_4 . Such a reaction may not culminate in an ignition unless the temperature of the fuel, or of the N_2O_4 - air mixture, is increased. On the other hand, if water is added to the fuel blend, there should exist a water concentration in the resultant blend above which spontaneous ignition will not occur for any specific N_2O_4 - air mixture, irrespective of the temperature. The results of spontaneous ignition temperature (SIT) tests conducted on various 50/50 fuel blend - water mixtures are shown in Figure 12. This figure shows that, in general, increasing the water concentration in the blend increases the SIT of the liquid blend for any specific N_2O_4 - air mixture. For example, with 15 volume percent N_2O_4 , the SIT increases from 60° to 325° F when the concentration of water in the blend increases from 0 to 80 liquid volume percent.

B. SPONTANEOUS IGNITION CHARACTERISTICS OF VAPORIZED BLENDS IN CONTACT WITH N_2O_4 - AIR MIXTURES

In Reference 10, the Bureau of Mines found that the residence time of the fuel blend vapor in the ignition temperature apparatus affected the minimum SIT. This effect was investigated further by reducing the residence time from 60 to 10 seconds. The SIT for the fuel blend vapor - water vapor - air mixture on contact with N_2O_4 are given in Figure 13. For comparison, the corresponding curve for the fuel blend - air mixtures determined with 60 seconds residence time is included in this figure. The results show that increasing the water content of the 50/50 fuel blend vapor increases the SIT on contact with N_2O_4 . To illustrate this, Figure 13 shows that, for a 50/50 fuel blend vapor concentration of 6 volume percent, increasing the water vapor concentration from 0 to 22 volume percent (product of 3.7 x 6) increases the SIT from 150° to 315° F.

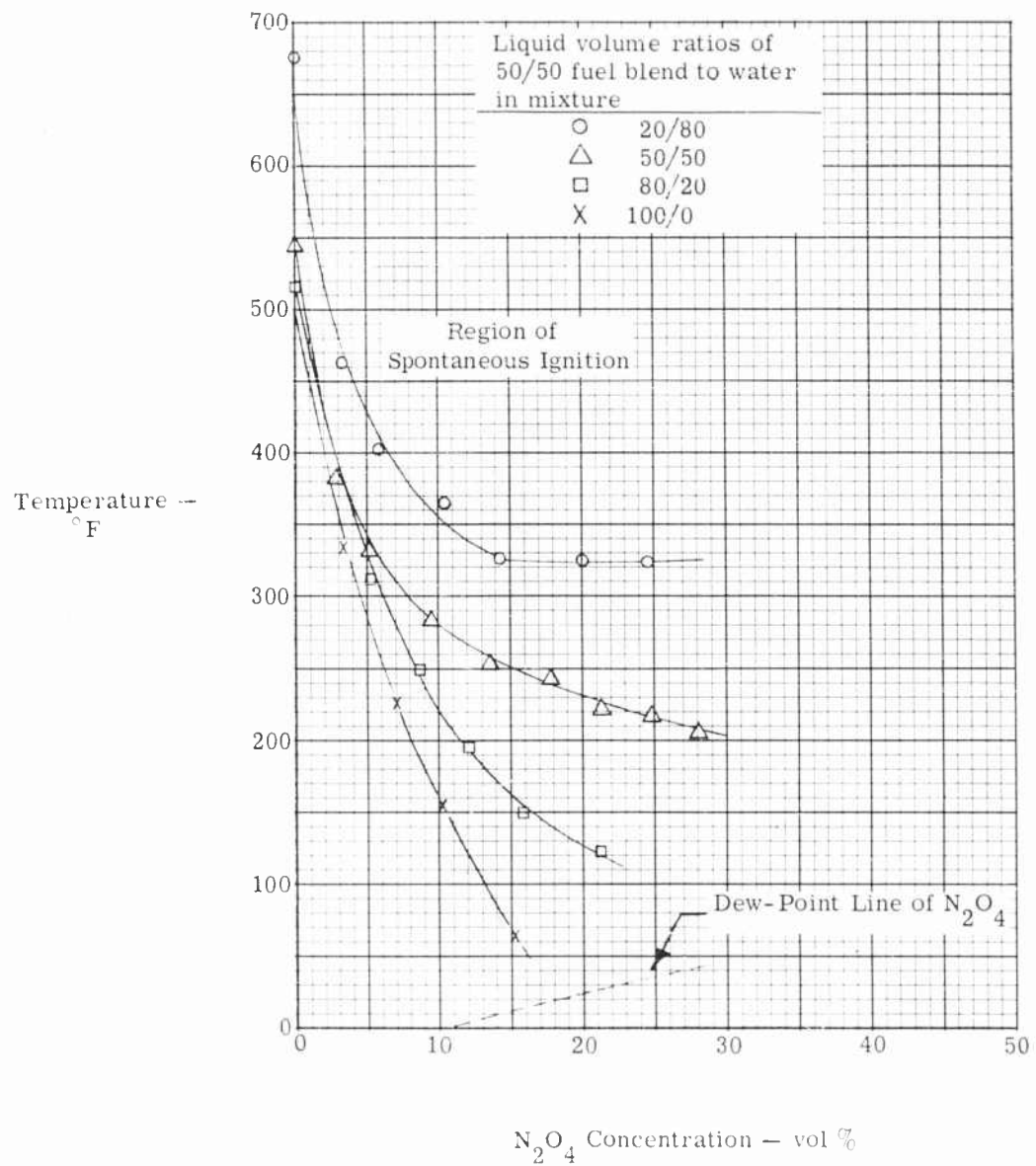


Figure 12. Minimum SIT of Various Liquid Blends of 50/50 Fuel and Water on Contact with N_2O_4 - Air Mixtures as a Function of N_2O_4 Concentration

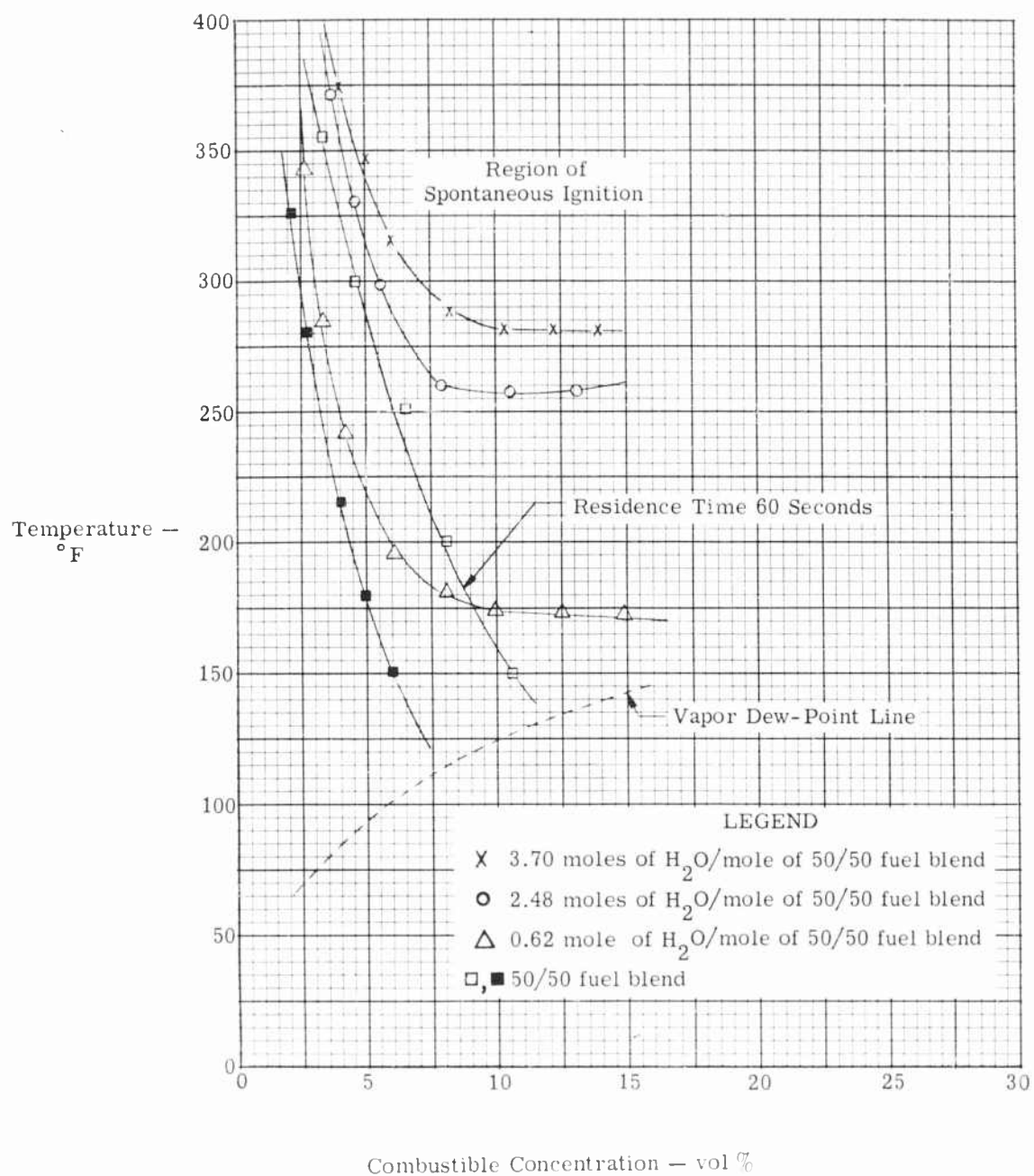


Figure 13. SIT of Vaporized 50/50 Fuel Blend — Water Mixtures in Air on Contact with N_2O_4 as a Function of Combustible Vapor Concentration for Residence Time of 10 Seconds

C. EFFECT OF WATER VAPOR ON THE LOWER LIMIT OF FLAMMABILITY OF 50/50
FUEL BLEND IN AIR

Flammability limits tests were performed with fuel blend vapor and water vapor (Reference 9). The results of the tests showed that the presence of water vapor to the extent of 21.4 volume percent has essentially no effect on the lower limit of flammability of the 50/50 fuel blend in air.

SECTION VI
REFERENCES

1. AFFTC, Edwards Air Force Base, "Storable Propellant Data for the Titan II Program," Bell Aerosystems Company, Quarterly Progress Report No. 2, FTRL-TOR-61-21, January 1961.
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3. Air Force Ballistic Missile Division, "Storable Propellant Data for the Titan II Program," Bell Aerosystems Company, Progress Report, AFBMD TR-61-55, July 1961.
4. "The Standard Method of Test for Flash and Fire Points by Means of Cleveland Open Cup," ASTM-D92-52, Part 5, 1955.
5. Fiegl, F., "Spot Tests - Organic Applications," Elsevier Publishing Company, p. 120, 1954.
6. AFBM Exhibit 60-13, "General Specification of Environmental Requirements for Missile Equipment of the WS 107A-2 Titan II," Revision B, p. 28, 22 August 1961.
7. Air Force Ballistic Systems Division, "Storable Propellant Data for the Titan II Program," Bell Aerosystems Company, Progress Report, AFBSD TR-61-35, November 1961.
8. Lewis, B. and von Elbe, G., "Combustion, Flames, and Explosions of Gases," Academic Press, New York, pp. 83-88, 1951.
9. "Flammability Characteristics of Hydrazine - Unsymmetrical Dimethyl Hydrazine - Nitrogen Tetroxide - Air - Water Mixtures," Explosives Research Laboratory Final Report No. 3844, 12 December 1961, Bell Aerosystems Company Contract 14-09-050-2211.
10. "Flammability Characteristics of Hydrazine - Unsymmetrical Dimethyl Hydrazine - Nitrogen Tetroxide - Air Mixtures," Explosives Research Laboratory Final Report No. 3806, 15 February 1961, Bell Aerosystems Company Contract 14-09-050-2137.

APPENDIX A
DEFINITION OF RATINGS GIVEN TO MATERIALS FOR USE WITH PROPELLANTS

METALS

- A: These metals are suitable for unrestricted use with propellants. The corrosion rates are less than 1 MPY. Typical uses are storage containers and valves where the propellant is in constant contact.
- B: These metals are for restricted use such as transient or limited contact. The corrosion rates are a maximum of 5 MPY. Typical uses are for valves and lines on aerospace ground equipment, for hardware which contacts the propellant intermittently in the liquid and vapor phases, and for pumps and feed lines in which the residence time is limited to loading and unloading.
- C: These metals have limited resistance, and corrosion rates are between 5 and 50 MPY. Typical use is where the metals are exposed to spillage and momentary contact, such as test stand hardware and aerospace ground equipment. Also, these metals have application where corrosion can be tolerated to the extent that it will not affect functional operations.
- D: These metals are not recommended for use because their corrosion rates exceed 50 MPY and/or they cause propellant decomposition.

NONMETALS

Government specifications^a on rubbers and plastic-fabricated parts intended for packings and seals show that the physical property effects to be minimized are volume change, durometer

a — Government Specifications:

MIL-R-2765A	Rubber, Synthetic, Oil Resistant (Sheet, Strip, and Molded Shapes)
MIL-R-3065B	Rubber-Fabricated Parts
MIL-R-8791A	Retainer Packing, Hydraulic and Pneumatic, Tetrafluorethylene
HH-P-131C	Packing, Metallic and Nonmetallic, Plastic
HH-P-166A	Packing, Nonmetallic

change, effect on media, and visual examination in terms of surface appearance. The specifications contain different values for volume change and durometer change. Using the ranges called for in the reviewed specifications, the following ratings were derived for the nonmetals.

Ratings	A	B	C	D
Volume Change, %	0 to +25	-10 to +25	-10 to +25	< -10 or > +25
Durometer Reading Change	±3	±10	±10	< -10 or > +10
Effect on Propellant	None	Slight Change	Moderate Change	Severe
Visual Examination	No Change	Slight Change	Moderate Change	Dissolved, severely blistered, or cracked

Definitions for these ratings are as follows:

- A: Satisfactory for service under conditions indicated.
- B: Use with knowledge that the material will swell, shrink, and/or change in hardness; also other slight changes may occur on the material and/or in the propellant.
- C: Satisfactory for ground support where preventive maintenance can be scheduled. Also good for actual missile service where discoloration of propellant and/or extracted residue is tolerable.
- D: Unsatisfactory for use.

APPENDIX B
VENDOR INDEX FOR NONMETALLIC MATERIALS

<u>PLASTICS</u>	<u>COMPOSITION</u>	<u>SOURCE</u>
Aclar 191	Fluorohalocarbon	Allied Chemical and Dye Corp. New York, N. Y.
Amerplate	Polyvinyl chloride	Amercoat Corp., Southgate, Calif.
Capran 391	Polyamide	Allied Chemical and Dye Corp., New York, N. Y.
Formulation 39	Cross-linked polyethylene	Aeronautical Systems Division, Dayton, Ohio
Kynar	Vinylidene fluoride	Pennsalt Chemical Corp., Phila., Pa.
<u>ELASTOMERS</u>		
X7000 dash No. 1-7 and 9-11	Ethylene propylene	Seals East Orange Inc., East Orange, N. J.
Formula 132	Ethylene propylene	Reaction Motors Division, Denville, N. J.
940 x 559	Butyl	Precision Rubber Products Co., Dayton, Ohio
B480-7	Butyl	Parker Seal Co, Los Angeles, Calif.
Formulation 35	Cis-4-polybutadiene	Aeronautical Systems Division, Dayton, Ohio
Formulation 121	Butyl	Aeronautical Systems Division, Dayton, Ohio
18007 and 18057	Fluororubbers	Precision Rubber Products Co., Dayton, Ohio
<u>COATINGS</u>		
Proseal 333	Butyl	Coast Proseal & Mfg. Co., Los Angeles, Calif.
Markal DA8	Aluminum	Markal Co., Chicago, Ill.
DA 9	Aluminum	Markal Co., Chicago, Ill.
Aluminous	Aluminum	Aluminous Coatings Inc., Hollandale, Fla.
Rezklad	Epoxy	Atlas Mineral Products Co., Merztown, Pa.

<u>GRAPHITES</u>	<u>COMPOSITION</u>	<u>SOURCE</u>
Graphitars 14, 38, 86	Carbon - Graphite	U. S. Graphite Co., Saginaw, Mich.
CCP-72	Carbon - Graphite	National Carbon Co., Pittsburgh, Pa.
<u>RUBBER GLOVES</u>		
Davol	Natural	Davol Rubber Co., Providence, R.I.
Ebonettes	Natural rubber & Neoprene	Pioneer Co., Unknown
Amber Plus	Unknown	Pretty Products Inc., Coshocton, Ohio
Latex Seamless	Natural rubber	Unknown
National Glove	Unknown	Unknown
<u>MISCELLANEOUS</u>		
Bal Seal	Teflon covered seal	Balsells Engineering Co., La Habra, Calif.
Omniseal	Teflon covered seal	Reid Enterprises Inc., Long Beach, Calif.
<u>LUBRICANTS</u>		
PD 788	Fluorocarbon	Frankford Arsenal, Phila., Pa.